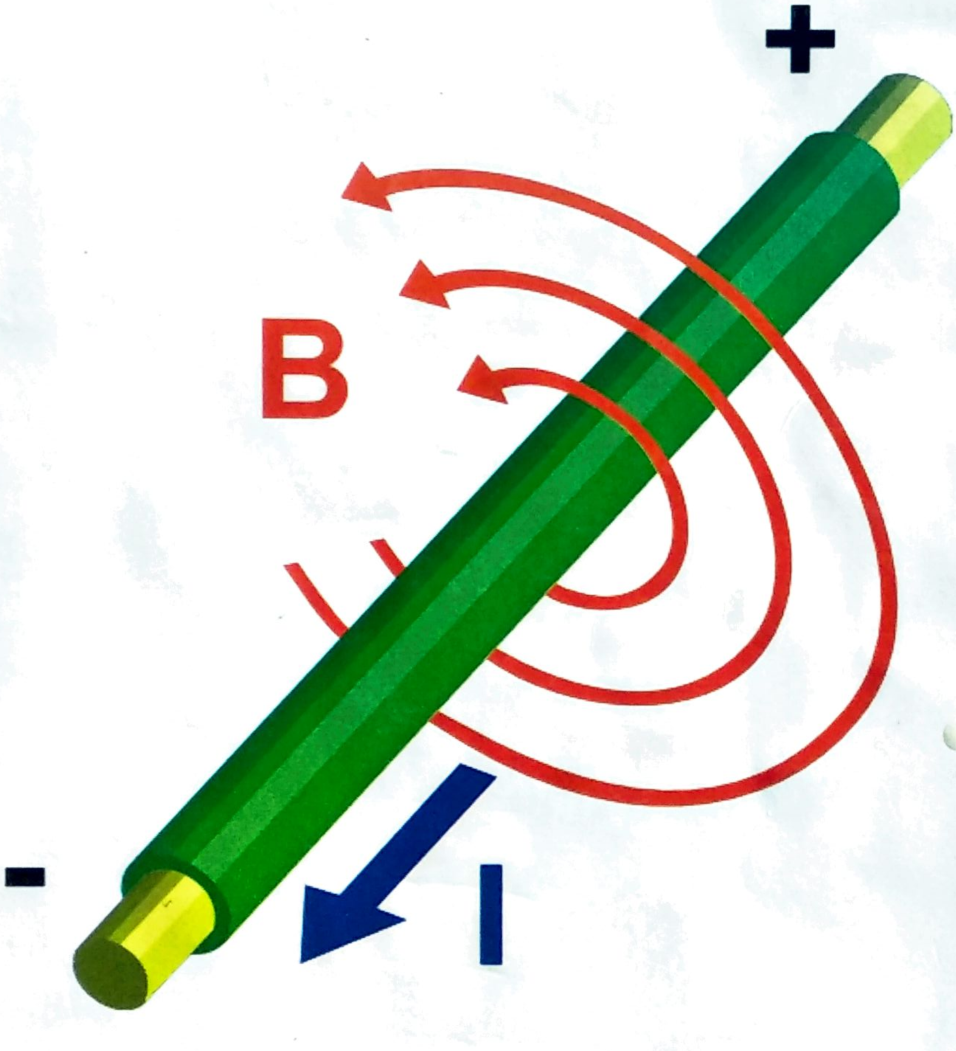
ELECTROMAGNETIC THEORY

CSIR-UGC-NET DEC. 2018 | GATE 2019



Assignment & Previous Years' Question

NET | GATE | TIFR | JEST

CAREER ENDEAVOUR
Best Institute for IIT-JAM, NET & GATE
www.careerendeavour.com

CONTENTS

ELECTROMAGNETIC THEORY

Assignment & Previous Years' Questions

LEVEL-1

PAGE NO.

Assignment-01 01-07
Assignment-02 08-15
Assignment-03 16-21
Assignment-04 22-27
Assignment-05 28-32
Assignment-06 33-40
Assignment-07 41-53
Assignment-08 54-64
Assignment-09 65-66
Assignment-10 67-68
Assignment-11 69-71
Assignment-12 72-74
Assignment-13 75-77
Assignment-14 78-79

LEVEL-2

Assignment-01 80-82
Assignment-02 83-86
Assignment-03 87-92
Assignment-04 93-95
Assignment-05 96-98
Assignment-06 99-100
Assignment-07 101-104
Assignment-08 105-108
Assignment-09 109-113

LEVEL-1

CAREER ENDEAVOUR

Best Institute for IIT-JAM, NET & GATE

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

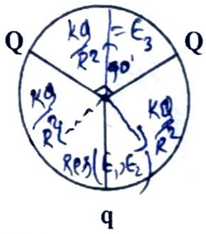
Assignment-1 : COULOMB'S & GAUSS LAW

1. Three charges are located on the circumference of a circle of radius 'R' as shown in the figure below. The two charges Q subtend an angle 90° at the centre of the circle. The charge 'q' is symmetrically placed with respect to the charges Q. If the electric field at the centre of the circle is zero, what is the magnitude of Q?

$E = \text{Res}(E_1, E_2) - E_3$ $\quad R = 2q\cos\frac{\theta}{2}$

$0 = 2\frac{kQ}{R^2}\cdot\cos 45' - \frac{kq}{R^2}$

$Q = q/\sqrt{2}$



[NET Dec. 2012]

(a) $q/\sqrt{2}$ (b) $\sqrt{2}q$ (c) 2q (d) 4q

2. Two points charges $+q_1$ and $+q_2$ are fixed with a finite a distance 'd' between them. It is desired to put a third charge q_3 in between these two charges on the line joining them so that the charge q_3 is in equilibrium. That is:
(a) Possible only if q_3 is positive (b) Possible only if q_3 is negative
(c) Possible irrespective of the sign of q_3. (d) Not possible at all.

3. In a region of electrostatic field which of the following statements is true for a charged particle :
(a) There exists only one stable equilibrium point
(b) Many stable equilibrium points may exist.
(c) No stable equilirium point exists.
(d) Number of stable equilibrium points depends on how the field is produced

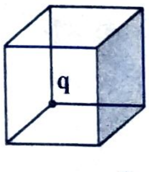
4. Consider two point charges q and λq located at the points, $x = a$ and $x = \mu a$, respectively. Assuming that the sum of the two charges is constant, what is the value of λ for which the magnitude of the electrostatic force is maximum? [JEST 2015]

(a) μ (b) 1 (c) $\frac{1}{\mu}$ (d) $1+\mu$

5. A charge distribution has the charge density given by $\rho = Q\{\delta(x-x_0) - \delta(x+x_0)\}$. For this charge distribution the electric field at $(2x_0, 0, 0)$ [GATE 2013]

(a) $\frac{2Q\hat{x}}{9\pi\epsilon_0 x_0^2}$ (b) $\frac{Q\hat{x}}{4\pi\epsilon_0 x_0^3}$ (c) $\frac{Q\hat{x}}{4\pi\epsilon_0 x_0^2}$ (d) $\frac{Q\hat{x}}{16\pi\epsilon_0 x_0^2}$

6. A point charge 'q' sits at a corner of a cube of side 'a', as shown in the figure on the right. The flux of the electric field vector through the shaded side is [TIFR 2013]



(a) $\frac{q}{8\varepsilon_0}$ (b) $\frac{q}{16\varepsilon_0}$ (c) $\frac{q}{24\varepsilon_0}$ (d) $\frac{q}{6\varepsilon_0}$

7. A static charge distribution gives rise to an electric field of the form $\vec{E} = \alpha\left(1 - e^{-r/R}\right)\frac{\hat{r}}{r^2}$, where α and R ar positive constants. The charge contained within a sphere of radius R, centred at the origin is:

(a) $\pi\alpha\varepsilon_0 \frac{e}{R^2}$ (b) $\pi\alpha\varepsilon_0 \frac{e^2}{R^2}$ (c) $4\pi\alpha\varepsilon_0 \frac{R}{e}$ (d) $\pi\alpha\varepsilon_0 \frac{R^2}{e}$ **[NET Dec. 2011]**

8. Consider a hollow charged shell of inner radius 'a' and outer radius 'b'. The volume charge density is $\rho(r) = \frac{k}{r^2}$ (where k is a constant) in the region $a < r < b$. The magnitude of the electric field produced at distance $r > a$ is: **[NET Dec. 2012]**

(a) $\frac{k(b-a)}{\varepsilon_0 r^2}$ for $r > a$

(b) $\frac{k(b-a)}{\varepsilon_0 r^2}$ for $a < r < b$ and $\frac{kb}{\varepsilon_0 r^2}$ for $r > b$

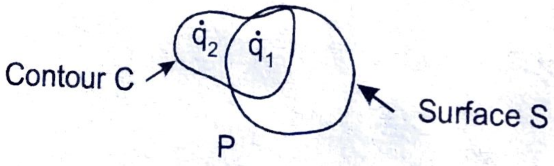
(c) $\frac{k(r-a)}{\varepsilon_0 r^2}$ for $a < r < b$ and $\frac{k(b-a)}{\varepsilon_0 r^2}$ for $r > b$

(d) $\frac{k(r-a)}{\varepsilon_0 a^2}$ for $a < r < b$ and $\frac{k(b-a)}{\varepsilon_0 a^2}$ for $r > b$

9. A solid sphere of radius R has a charge density, given by $\rho(r) = \rho_0\left(1 - \frac{ar}{R}\right)$, where r is the radial coordinate and ρ_0, a and R are positive constants. If the magnitude of the electric field at $r = R/2$ is 1.25 times that at $r = R$, then the value of a is **[NET June 2014]**

(a) 2 (b) 1 (c) $\frac{1}{2}$ (d) $\frac{1}{4}$

10. Consider a set of two stationary point charges q_1 and q_2 as shown in the figure. Which of the following statements is correct? **[GATE 2002]**



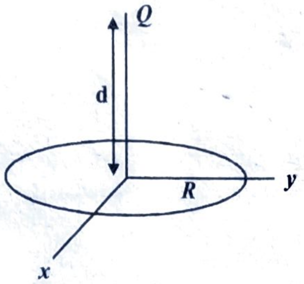
(a) The electric field at P is independent of q_2

(b) The electric flux crossing the closed surface S is independent of q_2

(c) The line integral of the electric field $\vec{E}$ over the closed contour C depends on q_1 and q_2.

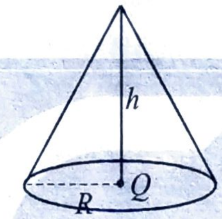
(d) $\vec{\nabla}.\vec{E} = 0$ everywhere

11. The flux of electric field through a circle of radius R placed in the x-y plane with its centre at the origin due to a point charge Q placed at (0, 0, d) is



(a) $\frac{Q}{2\varepsilon_0}\left[1-\frac{d}{\left(d^2+R^2\right)^{1/2}}\right]$ (b) $\frac{Q}{2\varepsilon_0}\frac{d^3}{\left(d^2+R^2\right)^{3/2}}$ (c) $\frac{Q}{4\pi\varepsilon_0}\frac{d}{R}$ (d) $\frac{Q}{4\varepsilon_0}\frac{R^2}{d^2}$

12. Consider a charge Q at the origin of 3-dimensional coordinate system. The flux of the electric field through the curved surface of a cone that has a height 'h' and a circular base of radius R (as shown in the figure) is



(a) $\frac{Q}{\epsilon_0}$ (b) $\frac{Q}{2\epsilon_0}$ (c) $\frac{hQ}{R\epsilon_0}$ (d) $\frac{QR}{2h\epsilon_0}$

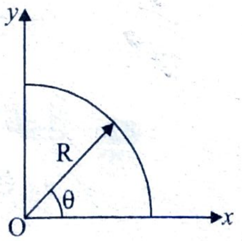
13. The potential due to an electric dipole p placed at the origin is known to be of the form $\phi(r) = p.r/r^3$. The total flux of the electric field through a spherical surface of radius R with the dipole at the centre is given by

(a) Zero (b) $-\frac{2\pi}{3}\frac{|p|}{R}$ (c) $+\frac{2\pi}{3}\frac{|p|}{R}$ (d) $+\frac{4\pi}{3}\frac{|p|}{R}$

14. If $\vec{D} = \left(2y^2+z\right)\hat{i} + 4xy\hat{j} + x\hat{k}$, units of C/m^2, the total charge enclosed by the cube $0 \le x < 1, 0 \le y < 1,\ 0 \le z \le 1$

(a) 2C (b) 4C (c) 0 C (d) 1C

15. A segment of a circular wire of radius R, extending from $\theta = 0$ to $\pi/2$, carries a constant linear charge density, λ. The electric field at origin 'O' is:

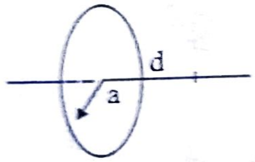


(a) $\frac{\lambda}{4\pi\varepsilon_0 R}(-\hat{x}-\hat{y})$ (b) $\frac{\lambda}{4\pi\varepsilon_0 R}\left(-\frac{1}{\sqrt{2}}\hat{x}-\frac{1}{\sqrt{2}}\hat{y}\right)$ (c) $\frac{\lambda}{4\pi\varepsilon_0 R}\left(-\frac{1}{2}\hat{x}-\frac{1}{2}\hat{y}\right)$ (d) 0

16. The concentric thin spherical shells of radii a, b and c $(a < b < c)$ carry uniform surface electric charge densities $\sigma, -\sigma$ and σ, respectively. The electric potential at the surface of the outermost shell is

(a) $\frac{\sigma}{\varepsilon_0}(c - b + a)$ (b) $\frac{\sigma}{\varepsilon_0}\left(\frac{c^2}{a} - \frac{b^2}{a} + a\right)$ (c) $\frac{\sigma}{\varepsilon_0}\left(\frac{c^2}{b} - b\frac{a^2}{b}\right)$ (d) $\frac{\sigma}{\varepsilon_0}\left(c - \frac{b^2}{c} + \frac{a^2}{c}\right)$

17. A very circular wire of radius a carries electric charge of uniform liner density ρ. On its axis, the magnitude of the electric field attains its maximum value at a perpendicular distance d form the plane of the wire (see the figure below). The value of d is



(a) 0 (b) 0.32 a (c) 0.50a (d) $a/\sqrt{2}$

18. Consider the plane defined by $(x, y, z = 10\ \text{m})$. If it carries a charge of $20\ \text{nC/m}^2$, what is the electric field intensity at the origin?

(a) $-720\pi\hat{k}\frac{\text{V}}{\text{m}}$ (b) $-360\pi\hat{k}\frac{\text{V}}{\text{m}}$ (c) $-72\pi\hat{k}\frac{\text{V}}{\text{m}}$ (d) $-18\ \pi\hat{k}\frac{\text{V}}{\text{m}}$

19. A circular loop of radius R carries a uniform line charge density λ. The electric field, calculated at a distance z directly above the center of the loop, is maximum if z is equal to, **[JEST 2015]**

(a) $\frac{R}{\sqrt{3}}$ (b) $\frac{R}{\sqrt{2}}$ (c) $\frac{R}{2}$ (d) $2R$

20. Consider an infinite line charge with linear charge density λ. At a distance r from the line, the electrostatic potential has the form **[NET 2008]**

(a) $\frac{\lambda a}{4\pi\varepsilon_0 r}$ (b) $\frac{\lambda}{2\pi\varepsilon_0}\exp(-r/a)$ (c) $\frac{\lambda}{2\pi\varepsilon_0}\ln\left(r/a\right)$ (d) $\frac{\lambda}{4\pi\varepsilon_0}\frac{r}{a}$

21. Consider an infinite horizontal surface with fixed surface charge density σ, where $\hat{n}$ is the upward normal to the surface. If an electric field $\vec{E}_b = E\hat{n}$ is applied from below, the electric field $\vec{E}_a$ in the region above the surface is: **[NET 2008]**

(a) $\vec{E}_a = \vec{E}_b - \frac{\sigma}{2\varepsilon_0}\hat{n}$ (b) $\vec{E}_a = \vec{E}_b + \frac{\sigma}{2\varepsilon_0}\hat{n}$

(c) $\vec{E}_a = \vec{E}_b - \frac{\sigma}{\varepsilon_0}\hat{n}$ (d) $\vec{E}_a = \vec{E}_b + \frac{\sigma}{\varepsilon_0}\hat{n}$

22. An electric charge, $+Q$ is placed on the surface of a solid, conduction sphere of radius a. The distance measured from the centre of the sphere is denoted as r. Then : **[GATE 2003]**

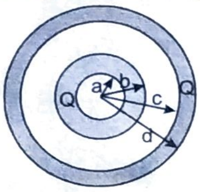
(a) The charge gets distributed uniformly through the volume of the sphere
(b) The electrostatic potential has the same value for $r < a$
(c) An equal and opposite charge gets induced in the bottom half of the sphere
(d) The electric field is given by $1/\left(4\pi\varepsilon_0 r^2\right)$ for $r < a$

23. A shere of radius R has uniform volume charge density. The electric potential at a point r (r < R) is **[GATE 2006]**

(a) Due to the charge inside a sphere of radius r only
(b) Due to the entire charge of the sphere
(c) Due to charge in the spherical shell of inner and outer radii r and R, only
(d) Independent of r

Common data for Q. 24 and Q.25.

Consider two concentric conducting spherical shells with inner and outer radii a, b and c, d as shown in the figure. Both the shells are given Q amount of positive charges.



24. The electric field in different regions are : **[GATE 2008]**

(a) $\vec{E}=0$ for $r<a$; $\vec{E}=\frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $a<r<b$; $\vec{E}=0$ for $b<r<c$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r>d$

(b) $\vec{E}=\frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r<a$; $\vec{E}=0$ for $a<r<b$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $b<r<c$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r<d$

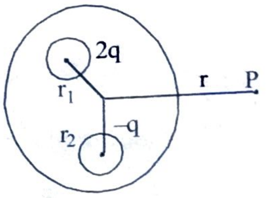
(c) $\vec{E}=\frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r<a$; $\vec{E}=0$ for $a<r<b$; $\vec{E}=0$ for $b<r<c$; $\vec{E}=\frac{2Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r>d$

(d) $\vec{E}=0$ for $r<a$; $\vec{E}=0$ for $a<r<b$; $\vec{E}=\frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $b<r<c$; $\vec{E}=\frac{2Q}{4\pi\varepsilon_0 r^2}\hat{r}$ for $r>d$

25. In order to have equal surface charge densities on the outer surfaces of both the shells, the following conditions should be satisfied **[GATE 2008]**

(a) $d=4b$ and $c=2a$
(b) $d=2b$ and $c=\sqrt{2}a$
(c) $d=\sqrt{2}b$ and $c>a$
(d) $d>b$ and $c=\sqrt{2}a$

26. A spherical conductor of radius R has two cavities centered at r_1 and r_2 respectively from the centre of the conductor. The cavities contain point charges +2q and –q at their respective centers as shown in the figure. The magnitude of the electric field at a point P is :



(a) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

(b) $\frac{1}{4\pi\varepsilon_0}\left[\left(\frac{2q}{(r-r_1)^2}\right)^2+\left(\frac{-q}{(r-r_2)^2}\right)^2\right]^{1/2}$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-r_1-r_2)^2}$

(d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-r_1)^2+(r-r_2)^2}$

27. A uniformly charged thin spherical shell of radius R carries a total charge q. At a point inside (r < R) the spherical shell, if E and V are intensity of the electric field and electric potential respectively then :

(a) Both E and V are zero.
(b) E is zero but V is a nonzero constant.
(c) E is proportional to $1/r^2$ and V is proportional to $1/r$.
(d) Both E and V are nonzero constants.

D.Y.

28. A hollow, closed conductor is placed in an external electric field $\vec{E}$. Then, at equilibrium, the electric field within the cavity is:

(a) $\vec{E}$
(b) 0
(c) Can be less than $\vec{E}$ but non-zero
(d) Greater than $\vec{E}$

29. Four equal charges of $+Q$ each are kept at the vertices of a square of side R. A particle of mass m and charge $+Q$ is placed in the plane of the square at a short distance $a (\ll R)$ from the center. If the motion of the particle is confined to the plane, it will undergo small oscillations with an angular frequency

[NET June 2016]

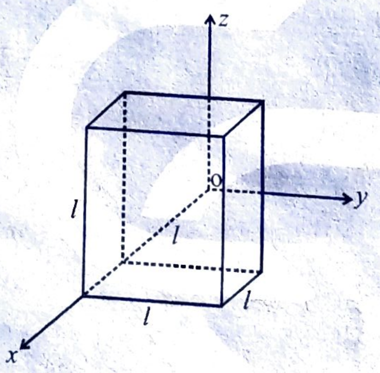
(a) $\sqrt{\frac{Q^2}{2\pi\varepsilon_0 R^3 m}}$ (b) $\sqrt{\frac{Q^2}{\pi\varepsilon_0 R^3 m}}$ (c) $\sqrt{\frac{\sqrt{2}Q^2}{\pi\varepsilon_0 R^3 m}}$ (d) $\sqrt{\frac{Q^2}{4\pi\varepsilon_0 R^3 m}}$

30. A solid, insulating sphere of radius 1 cm has charge 10^{-7} C distributed uniformly over its volume. It is surrounded concentrically by a conducting thick spherical shell of inner radius 2 cm, outer radius 2.5 cm and is charged with -2×10^{-7} C. What is the electrostatic potential in Volts on the surface of the sphere ?

[JEST 2017]

31. For an electric field $\vec{E} = k\sqrt{x}\hat{x}$, where k is a non-zero constant, total charge enclosed by the cube as shown below is

[JEST 2017]



(a) 0 (b) $k\varepsilon_0 l^{5/2}\left(\sqrt{3}-1\right)$ (c) $k\varepsilon_0 l^{5/2}\left(\sqrt{5}-1\right)$ (d) $k\varepsilon_0 l^{5/2}\left(\sqrt{2}-1\right)$

32. A conducting sphere of radius R is placed in a uniform electric field $\vec{E}_0$ directed along + z axis. The electric potential for outside points is given as :

$V_{out} = -E_0\left(1-\frac{R^3}{r^3}\right)r\cos\theta$, where r is the distance from the centrer and θ is the polar angle. The charge density on the surfae of the sphere is :

(a) $3\varepsilon_0 E_0 \cos\theta$ (b) $\varepsilon_0 E_0 \cos\theta$ (c) $3\varepsilon_0 E_0 \cos\theta$ (d) $\frac{\varepsilon_0}{3} E_0 \cos\theta$

33. A particle of mass m and charge q is constrained to move along a straight line joining two other equal charges q fixed at $x = \pm a$. The time period of small oscillation is:

(a) $T = \frac{2\pi a}{q}\sqrt{\varepsilon_0 am}$ (b) $T = \frac{4\pi a}{q}\sqrt{\pi\varepsilon_0 am}$ (c) $T = \frac{a}{q}\sqrt{\pi\varepsilon_0 am}$ (d) $T = \frac{2\pi a}{q}\sqrt{\pi\varepsilon_0 am}$

34. Two point charges q and 4q are located at r_1 and r_2, respectively, on the xy-plane. The magnitude Q and location R of a third charge to be placed on the plane such that total force on the each of the three charges vanishes, are

(a) $Q=-4q/9$ and $R=(2r_1+r_2)/3$ (b) $Q=-4q/5$ and $R=(r_1+2r_2)/3$

(c) $Q=-4q/25$ and $R=(16r_1+r_2)/\sqrt{17}$ (d) $Q=-9q/4$ and $R=(r_1+2r_2)/3$

[TIFR 2018]

35. The electrostatic charge density $\rho(r)$ corresponding to the potential

$$\varphi(r)=\frac{q}{4\pi\in_0}\frac{1}{r}\left(1+\frac{\alpha r}{2}\right)\exp(-\alpha r)$$

is $\rho=$

(a) $q\delta(r)-2q\alpha^3\exp(-\alpha r)$ (b) $q\delta(r)-q\frac{\alpha^3}{4}\exp(-\alpha r)$

(c) $q\delta(r)-q\frac{4\pi\alpha^3}{2}\exp(-\alpha r)$ (d) $-q\delta(r)-2q\alpha^3\exp(-\alpha r)$

[JEST 2018]

36. An electric charge distribution produces an electric field

$$\vec{E}=\left(1-e^{-\alpha r}\right)\frac{\vec{r}}{r^3}$$

where δ and α are constants. The net charge within a sphere of radius α^{-1} centred at the origin is

(a) $4\pi\in_0\left(1-e^{-1}\right)$ (b) $4\pi\in_0\left(1+e^{-1}\right)$ (c) $-4\pi\in_0\frac{1}{\alpha e}$ (d) $4\pi\in_0\frac{1}{\alpha e}$

[JEST 2018]

37. The charge density as a function of the radial distance r is given by

$$\rho(r)=\rho_0\frac{R^2-r^2}{R^2}$$

for $r<R$ and zero otherwise. The electric flux over the surface of an ellipsoid with axes $3R$, $4R$ and $5R$ centred at the origin is

(a) $\frac{4}{3\in_0}\pi\rho_0R^3$ (b) $\frac{8}{9\in_0}\pi\rho_0R^3$ (c) $\frac{8}{15\in_0}\pi\rho_0R^3$ (d) 0

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-2 : Electric Potential and Conductors

1. A conducting sphere of radius R is placed in a uniform electric field $\vec{E}_0$ directed along + z axis. The electric potential for outside points is given as :

$V_{out} = -E_0\left(1-\frac{R^3}{r^3}\right) r\cos\theta$, where r is the distance from the centrer and θ is the polar angle. The charge density on the surfae of the sphere is :

(a) $3\varepsilon_0 E_0 \cos\theta$ (b) $\varepsilon_0 E_0 \cos\theta$ (c) $3\varepsilon_0 E_0 \cos\theta$ (d) $\frac{\varepsilon_0}{3} E_0 \cos\theta$

2. The electrostatic potential due to a charge distribution is given by $V(r) = A\frac{e^{-\lambda r}}{r}$, where A and λ are constants. The total charge enclosed within a sphere of radius $1/\lambda$, with its origin at $r = 0$ is given by,

(a) $\frac{8\pi\varepsilon_0 A}{e}$ (b) $\frac{4\pi\varepsilon_0 A}{e}$ (c) $\frac{\pi\varepsilon_0 A}{e}$ (d) 0 **[JEST 2015]**

3. A static, spherically symmetric charge distribution is given by $\rho(r) = \frac{A}{r}e^{-Kr}$ where A and K are positive constants. The electrostatic potential corresponding to this charge distribution varies with r as **[NET June 2011]**

(a) $r\,e^{-Kr}$ (b) $\frac{1}{r}e^{-Kr}$ (c) $\frac{1}{r^2}e^{-Kr}$ (d) $\frac{1}{r}\left(1-e^{-Kr}\right)$

4. Three equal chrages Q are successively brought from infinity and each is placed at one of the three vertices of an equilateral tringle. Assuming the rest of the Universe as a whole to be neutral, the energy E_0 of the electrostatic field will increase, successively, to **[TIFR 2012]**

$E_0+\Delta_1,\ E_0+\Delta_1+\Delta_2,\ E_0+\Delta_1+\Delta_2+\Delta_3$ Where $\Delta_1 : \Delta_2 : \Delta_3 =$

(a) 1 : 2 : 3 : (b) 1 : 1: 1 (c) 0 : 1 : 1 (d) 0 : 1 : 2

5. The electric fields outside ($r > R$) and inside ($r < R$) a solid sphere with a uniform volume charge density are given by $\vec{E}_{r>R} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$ and $\vec{E}_{r<R} = \frac{1}{4\pi\epsilon_0}\frac{q}{R^3}r\hat{r}$ respectively, while the electric field outside a spherical shell with a uniform surface charge density is given by $\vec{E}_{r>R} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$, q being the total charge. The correct ratio of the electrostatic energies for the second case to the first case is **[JEST 2013]**

(a) 1:3 (b) 9:16 (c) 3:8 (d) 5:6

6. One of electrostatic boundary conditions for the potential V for a surface carrying a surface charge density σ can be written as

(a) $V_{\text{above}} - V_{\text{below}} = -\dfrac{\sigma}{\epsilon_0}$ (b) $V_{\text{above}} - V_{\text{below}} = \dfrac{\sigma}{\epsilon_0}$

(c) $\dfrac{\partial V_{\text{above}}}{\partial n} - \dfrac{\partial V_{\text{below}}}{\partial n} = \dfrac{\sigma}{\epsilon_0}$ (d) $\dfrac{\partial V_{\text{above}}}{\partial n} - \dfrac{\partial V_{\text{below}}}{\partial n} = -\dfrac{\sigma}{\epsilon_0}$

7. In an electrostatic boundary value problem, the surface charge density σ is specified at $x = 0$. The corresponding boundary condition for potential V can be written as

(a) $\left(\dfrac{\partial^2 V}{\partial x^2}\right)_{x=0} = \dfrac{1}{\varepsilon_0}\sigma(y.z)$ (b) $\left(\dfrac{\partial^2 V}{\partial x^2}\right)_{x=0} = -\dfrac{1}{\varepsilon_0}\sigma(y.z)$

(c) $\left(\dfrac{\partial V}{\partial x}\right)_{x=0} = +\dfrac{1}{\varepsilon_0}\sigma(y.z)$ (d) $\left(\dfrac{\partial V}{\partial x}\right)_{x=0} = -\dfrac{1}{\varepsilon_0}\sigma(y.z)$

8. The electrostatic potential V(x,y) in free space in a region where the charge density ρ is zero is given by $V(x,y) = 4e^{2x} + f(x) - 3y^2$. Given that the x-component of the electric field, E_x, and V are zero at the origin, f(x) is: **[NET June 2011]**

(a) $3x^2 - 4e^{2x} + 8x$ (b) $3x^2 - 4e^{2x} + 16x$ (c) $4e^{2x} - 8$ (d) $3x^2 - 4e^{2x}$

9. If the electrostatic potential $V(r,\theta,\phi)$ in *a* charge free region has the form **[NET Dec. 2013]**

$V(r,\theta,\phi) = f(r)\cos\theta$, then the functional form of $f(r)$ (in the following *a* and *b* are constants) is

(a) $ar^2 + \dfrac{b}{r}$ (b) $ar + \dfrac{b}{r^2}$ (c) $ar + \dfrac{b}{r}$ (d) $a\ln\left(\dfrac{r}{b}\right)$

10. If the electrostatic potential in spherical polar coordinates is **[NET June 2014]**

$$\varphi(r) = \varphi_0 e^{-r/r_0}$$

where φ_0 and r_0 are constants, then the charge density at a distance $r = r_0$ will be

(a) $\dfrac{\varepsilon_0\varphi_0}{er_0^2}$ (b) $\dfrac{\varepsilon\varepsilon_0\varphi_0}{2r_0^2}$ (c) $\dfrac{\varepsilon_0\varphi_0}{er_0^2}$ (d) $-\dfrac{2\varepsilon\varepsilon_0\varphi_0}{r_0^2}$

11. A conducting sphere of radius R has charge +Q on its surface. If the charge on the sphere is doubled and its radius is halved, the energy associated with the electric field will : **[GATE 2004]**

(a) Increase four times (b) Increase eight times

(c) Remain the same (d) Decrease four times

12. Solving Poisson's equation $\nabla^2\varphi = -\rho_0/\varepsilon_0$ for the electrostatic potential $\varphi(\vec{x})$ in a region with a constant charge density ρ_0, two students find different answers, viz, **[TIFR 2014]**

$$\varphi_1(\vec{x}) = -\frac{1}{2}\frac{\rho_0 x^2}{\varepsilon_0} \text{ and } \varphi_2(\vec{x}) = -\frac{1}{2}\frac{\rho_0 y^2}{\varepsilon_0}$$

The reason why these different solutions are both correct is because

(a) space is isotropic and hence *x* and *y* are physically equivalent.

(b) We can add solutions of Laplace's equation to both $\varphi_1(\vec{x})$ and $\varphi_2(\vec{x})$

(c) The electrostatic energy is infinite for a constant charge density.

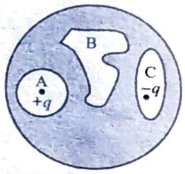
(d) The boundary conditions are different in the two cases.

13. A solid spherical conductor encloses 3 cavities, a cross-section of which are as shown in the figu A net charge $+q$ resides on the outer surface of the conductor. Cavities A and C contain point charg $+q$ and $-q$, respectively. **[TIFR 2015]**

The net charges on the surfaces of these cavities are

(a) $A = -q, B = q, C = 0$ (b) $A = -q, B = 0, C = -q$

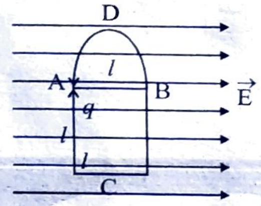
(c) $A = +q, B = 0, C = -q$ (d) $A = -q, B = 0, C = +q$



14. The one dimensional potential $V(x)$ for an electrostatic fields in a region of space which does not contain a charge has the form (in the following a and b are constants)

(a) $a \sin bx$ (b) ae^{-x^2} (c) $\frac{1}{2}ax^2$ (d) $ax + b$

15. A charge q is taken from point A to point B along two different paths ACB and ADB in an uniform electr field.



The difference in the work done between these two paths is:

(a) $3qlE - (\pi/2)lqE$ (b) 0 (c) $\frac{1}{2}\pi lqE$ (d) $3qlE$

16. The electrostatic potential is given by, $\Phi = 0$ at $x = 0$ and $x = a$; $\Phi = V$ $0 \le x \le a$. Then Φ is given b

$\Phi = \sum_{n=1}^{\infty} A_n \sin(\alpha x)$ where α is:

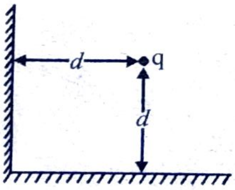
(a) $\frac{n\pi}{2}$ (b) $\frac{n\pi}{a}$ (c) $\frac{na}{\pi}$ (d) $\frac{na}{2\pi}$

17. A point charge 'q' of mass 'm' is kept at a distance 'd' below a grounded infinite conducting she which lies in the xy-plane. What is the value of 'd' for which the charge remains stationary?

(a) $q/4\sqrt{mg\pi\varepsilon_0}$ (b) $q/\sqrt{mg\pi\varepsilon_0}$ **[NET Dec. 2012]**

(c) There is no finite value of 'd' (d) $\sqrt{mg\pi\varepsilon_0}/q$

18. A point charge q is placed symmetrically at a distance d from two perpendicularly placed grounded conducting infinite plates as shown in the figure. The net force on the charge (in units of $1/4\pi\epsilon_0$) is



[NET Dec. 2013

(a) $\frac{q^2}{8d^2}(2\sqrt{2}-1)$ away from the corner (b) $\frac{q^2}{8d^2}(2\sqrt{2}-1)$ towards the corner

(c) $\frac{q^2}{2\sqrt{2}d^2}$ towards the corner (d) $\frac{3q^2}{8d^2}$ away from the corner

19. A grounded conducting sphere of radius 'a' is placed with its centre at the origin. A point dipole of dipole moment, $\vec{p} = p\hat{k}$ is placed at a distance 'd' along the x-axis, where $\hat{i}, \hat{k}$ are the units vector along the x and z-axes respectively. This leads to the formation of an image dipole of strength $\vec{p}\,'$ at a distance $d\,'$ from the centre along the x-axis. If $d\,' = \frac{a^2}{d}$, then $\vec{p}\,'$

(a) $-\frac{a^4 p}{d^4}\hat{k}$ (b) $-\frac{a^3 p}{d^3}\hat{k}$ (c) $-\frac{a^2 p}{d^2}\hat{k}$ (d) $-\frac{ap}{d}\hat{k}$

20. A charged particle is at a distance d from an infinite conducting plane maintained at zero potential. When released from rest, the particle reaches a speed u at a distance d/2 from the plane. At what distance from the plane will the particle reach the speed 2u? **[NET June 2014]**

(a) d/6 (b) d/3 (c) d/4 (d) d/5

21. A charge (−e) is placed in vacuum at the point (d, 0, 0), where d > 0. The region $x \le 0$ is filled uniformly with a metal. The electric field at the point $\left(\frac{d}{2}, 0, 0\right)$ is

(a) $-\frac{10e}{9\pi\varepsilon_0 d^2}(1,0,0)$ (b) $\frac{10e}{9\pi\varepsilon_0 d^2}(1,0,0)$ (c) $\frac{e}{\pi\varepsilon_0 d^2}(1,0,0)$ (d) $-\frac{e}{\pi\varepsilon_0 d^2}(1,0,0)$

22. A charge + q is kept at a distance of 2R from the center of a grounded conducting sphere of radius R. The image charge and its distance from the centre are, respectively: **[GATE 2004]**

(a) $-\frac{q}{2}$ and $\frac{R}{2}$ (b) $-\frac{q}{2}$ and $\frac{R}{4}$ (c) $-q$ and $\frac{R}{2}$ (d) $+\frac{q}{2}$ and $\frac{R}{2}$

23. The work done in bringing a charge +q from infinity in free space, to a position at a distance d in front of a semi-infinite grounded metal surface is: **[GATE 2005]**

(a) $-\frac{q^2}{4\pi\varepsilon_0(d)}$ (b) $-\frac{q^2}{4\pi\varepsilon_0(2d)}$ (c) $-\frac{q^2}{4\pi\varepsilon_0(4d)}$ (d) $-\frac{q^2}{4\pi\varepsilon_0(6d)}$

24. A solid spherical conductor has a conical hole made at one end, ending in a point B, and a small conical projection of the same shape and size at the opposite side, ending in a point A. A cross-section through the centre of the conductor is shown in the figure on the right. **[TIFR 2014]**

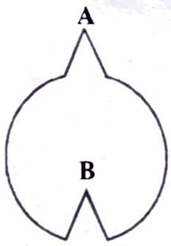
If now, a positive charge Q is transferred to the sphere, then

(a) The charge density at both A and B will be undefined.

(b) The charge density at A will be the same as the charge density at B.

(c) The charge density at A will be more than the charge density at B.

(d) The charge density at B will be more than the charge density at A.



25. A point charge +q placed at (0, 0, d) above a grounded infinite conducting plane defined by z = 0. There are no charges present anywhere else. What is the magnitude of electric field at (0, 0, −d) ?

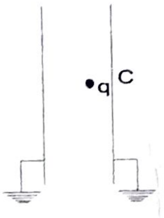
(a) $q/\left(8\pi\varepsilon_0 d^2\right)$ (b) $-\infty$ (c) 0 (d) $q/\left(16\pi\varepsilon_0 d^2\right)$ **[JEST 2012]**

26. A point charge is at a distance d from a metal plate. The force acting on the charge is:

(a) Proportional to $1/d^2$ and repulsive. (b) zero

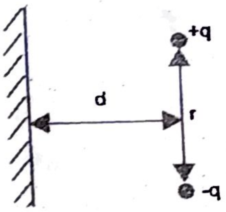
(c) Proportional to $1/d^2$ and attractive. (d) Proportional to 1/d and attractive.

27. A point charge q is kept at the mid-point between two large parallel grounded conducting plates. Assume no gravity. The charge is displaced a little towards the right plate. The charge will now,



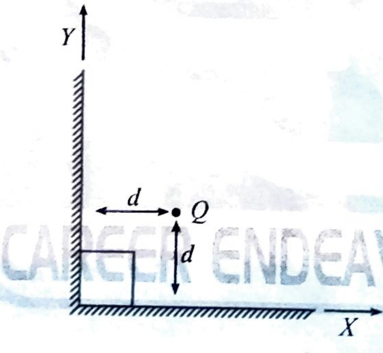
(a) Stay where it is
(b) Move towards the right plate
(c) Move towards the left plate
(d) Oscillate between the plates

28. Two equal and opposite charges are placed at a distance r from each other. A large metallic sheet is placed at a distance d from them as shown in the figure. Due to the presence of the sheet, the attractive force between the charges along the direction joining them



(a) decreases
(b) increases
(c) remains unchanged
(d) decreases or increases depending on the conductivity of the sheet.

29. A positive point charge Q is located at a distance d from two grounded conducting half planes perpendicular to each other, as shown in the figure. The force on Q caused by the charges induced on the planes is



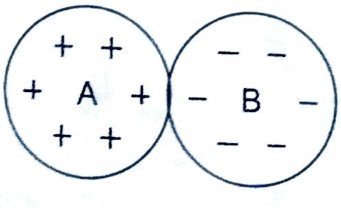
(a) 0

(b) $\frac{Q^2}{4\pi\in_0 d^2}\left(\frac{-1}{4}\hat{i}-\frac{1}{4}\hat{j}\right)$

(c) $\frac{Q^2}{4\pi\in_0 d^2}\left(\frac{-1}{2\sqrt{2}}\hat{i}-\frac{1}{2\sqrt{2}}\hat{j}\right)$

(d) $\frac{Q^2}{4\pi\in_0 d^2}\left(\frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{i}+\frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{j}\right)$

30. Two uniformly charged insulating solid spheres A and B, both of radius a, carry total charges $+Q$ and $-Q$, respectively. The spheres are placed touching each other as shown in the figure.

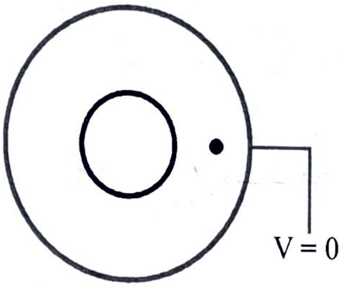


If the potential at the center of the sphere A is V_A and that at the center of B is V_B, then the difference $V_A - V_B$ is

[NET Dec. 2016]

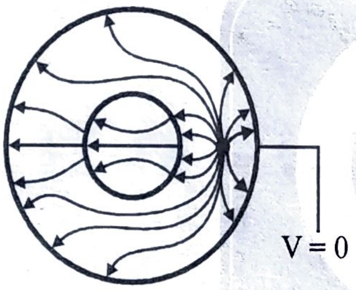
(a) $\frac{Q}{4\pi\varepsilon_0 a}$ (b) $\frac{-Q}{2\pi\varepsilon_0 a}$ (c) $\frac{Q}{2\pi\varepsilon_0 a}$ (d) $\frac{-Q}{4\pi\varepsilon_0 a}$

31. Two long hollow conducting cylinders, each of height h, are placed concentrically on the ground, as shown in the figure (top view). The outer cylinder is grounded, while the inner cylinder is insulated. A positive charge (the black dot in the figure) is placed between the cylinders at a height $h/2$ from the ground. **[TIFR 2017]**

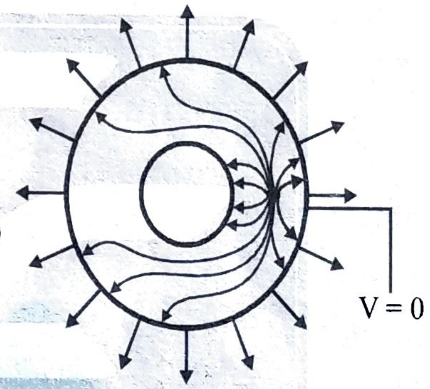


Which of the following figures gives the most accurate representation (top view) of the lines of force ?

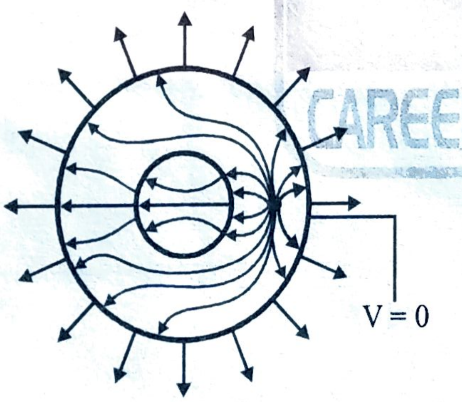
(a)



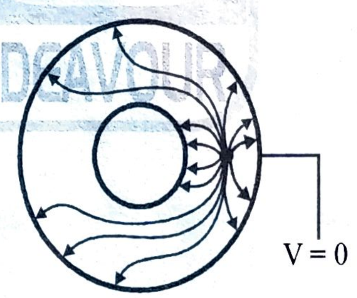
(b)



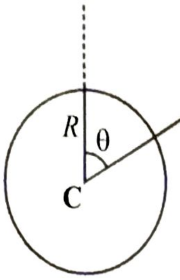
(c)



(d)



32. Consider a spherical shell with radius R such that the potential on the surface of the shell in spherical coor nates is given by $V(r=R,\theta,\varphi)=V_0\cos^2\theta$, where the angle θ is shown in the figure. There are no char except for those on the shell. The potential outside the shell at the point P a distance $2R$ away from its center (see figure) is **[TIFR 2017]**

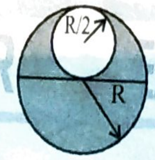


(a) $V=\frac{V_0}{8}(1+\cos^2\theta)$
(b) $V=\frac{V_0}{8}(1+2\cos^2\theta)$
(c) $V=\frac{V_0}{4}(1-\cos^2\theta)$
(d) $V=\frac{V_0}{2}(-2\cos\theta+\cos^3\theta)$

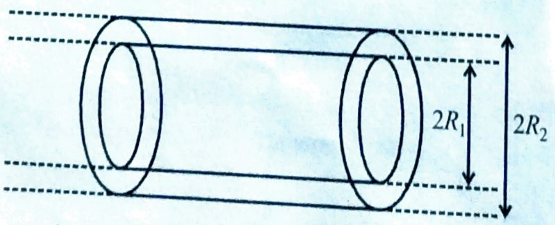
33. Consider a gounded conducting plane which is infinitely extended perpendicular to the y-axis at $y=0$. If a infinite line of charge per unit length λ runs parallel to x-axis at $y=d$, then surface charge density on th conducting plane is **[JEST 2017]**

(a) $\frac{-\lambda d}{(x^2+d^2+z^2)}$ (b) $\frac{-\lambda d}{(x^2+d^2+z^2)}$ (c) $\frac{-\lambda d}{\pi(x^2+d^2+z^2)}$ (d) $\frac{-\lambda d}{2\pi(x^2+d^2+z^2)}$

34. A sphere of radius R has a uniform charge density ρ. A sphere of smaller radius $\frac{R}{2}$ is cut out from th original sphere, as shown in the figure below. The centre of the cut out sphere lies at $z=\frac{R}{2}$. After th smaller sphere has been cut out, the magnitude of the electric field at $z=-\frac{R}{2}$ is $\frac{\rho R}{n\in_0}$. The value of th integer n is __________________



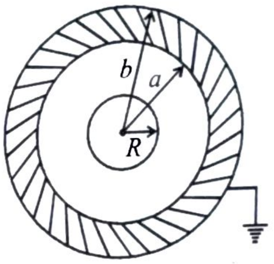
35. Two long hollow co-axial conducting cylinders of radii R_1 and R_2 $(R_1<R_2)$ are placed in vacuum as shown i the figure below.



The inner cylinder carries a charge $+\lambda$ per unit length and the outer cylinder carries a charge $-\lambda$ per un length. The electrostatic energy per unit length of this system is **[NET June 2017]**

(a) $\frac{\lambda^2}{\pi\varepsilon_0}\ln\left(\frac{R_1}{R_2}\right)$ (b) $\frac{\lambda^2}{4\pi\varepsilon_0}\left(\frac{R_2^2}{R_1^2}\right)$ (c) $\frac{\lambda^2}{4\pi\varepsilon_0}\ln\left(\frac{R_2}{R_1}\right)$ (d) $\frac{\lambda^2}{2\pi\varepsilon_0}\ln\left(\frac{R_2}{R_1}\right)$

36. A metal sphere of radius R with charge q is surrounded by a thick concentric spherical shell of inner radius a and outer radius b. The shell is grounded. The potential at the center of the sphere (with infinity as reference point) is given by



(a) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{b}+\frac{q}{R}-\frac{q}{a}\right)$ (b) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}\right)$

(c) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{b}-\frac{q}{R}\right)$ (d) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}-\frac{q}{a}\right)$

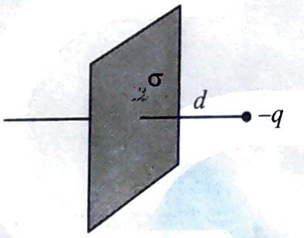
(e) $\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}+\frac{q}{a}\right)$

37. Two point charges $+3Q$ and $-Q$ are placed at $(0,0,d)$ and $(0,0,2d)$ respectively, above an infinite grounded conducting sheet kept in the xy-plane. At a point $(0,0,z)$, where $z \gg d$, the electrostatic potential of this charge configuration would approximately be **[NET Dec. 2017]**

(a) $\frac{1}{4\pi\varepsilon_0}\frac{d^2}{z^3}Q$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{2d}{z^2}Q$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{3d}{z^2}Q$ (d) $-\frac{1}{4\pi\varepsilon_0}\frac{d^2}{z^3}Q$

38. Calculate the self-energy, in Joules, of a spherical conductor of radius 8.5 cm, which carries a charge 100 μC. **[TIFR 2018]**

39. Consider an infinite plane with a uniform positive charge density σ as shown below



A negative point charge −q with mass m is held at rest at a distance d from the sheet and released. It will then undergo oscillatory motion. What is the time period of this oscillation?
[You may assume that the point charge can move freely though the charged plane without disturbing the charge density]. **[TIFR 2018]**

CSIR-UGC-NET/JRF|GATE-PHYSICS

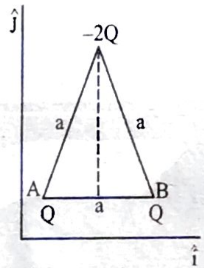
ELECTROMAGNETIC THEORY

Assignment-3 : Dielectric Polarization

1. A point charge q of mass m is released from rest at a distance d from an infinite grounded conducting plane (ignore gravity). How long does it takes for the charge to hit the plane ?

(a) $\dfrac{\sqrt{2\pi^3\varepsilon_0 md^3}}{q}$ (b) $\dfrac{\sqrt{2\pi^3\varepsilon_0 md}}{q}$ (c) $\dfrac{\sqrt{\pi^3\varepsilon_0 md^3}}{q}$ (d) $\dfrac{\sqrt{\pi^3\varepsilon_0 md}}{q}$

2. Charges Q, Q and -2Q are placed on the vertices of an equilateral triangle ABC of sides of length a, as shown in the figure **[NET June 2012]**



The dipole moment of this configuration of charges, irrespective of the choice of origin, is

(a) $+2aQ\,\hat{i}$ (b) $+\sqrt{3}aQ\,\hat{j}$ (c) $-\sqrt{3}aQ\,\hat{j}$ (d) 0

3. Consider an axially symmetric static charge distribution of the form, $\rho = \rho_0\left(\dfrac{r_0}{r}\right)^2 e^{-r/r_0}\cos^2\varphi$. The radial component of the dipole moment due to this charge distribution is **[NET June 2013]**

(a) $2\pi\rho_0 r_0^4$ (b) $\pi\rho_0 r_0^4$ (c) $\rho_0 r_0^4$ (d) $\pi\rho_0 r_0^4/2$

4. Two electric dipoles P_1 and P_2 are placed at (0, 0, 0) and (1, 0, 0) respectively, with both of them pointing in the +z direction. Without changing the orientations of the dipoles, P_2 is moved to (0, 2, 0). The ratio of the electrostatic potential energy of the dipoles after moving to that before moving is:

(a) $\dfrac{1}{16}$ (b) $\dfrac{1}{2}$ (c) $\dfrac{1}{4}$ (d) $\dfrac{1}{8}$

5. Four electric charges of strength Q, Q, −Q and −Q are placed respectively at the points (−b, 0), (b, 0), (0, −a) and (0, a) on the xy plane. At a distance d very far away from these charges (d >> a, b), the electric field will appear to be approximately that of **[GATE 2007]**

(a) A point charge (b) A dipole
(c) A quadrupole (d) A mixture of a dipole and a quadrupole

6. An insulating sphere of radius a carries a charge density $\rho(\vec{r}) = \rho_0\left(a^2 - r^2\right)\cos\theta;\ r < a$. The leading order term for the electric field at a distance d, far away from the charge distribution, is proportional to **[GATE 2010]**

(a) d^{-1} (b) d^{-2} (c) d^{-3} (d) d^{-4}

$q_{total} = 0$

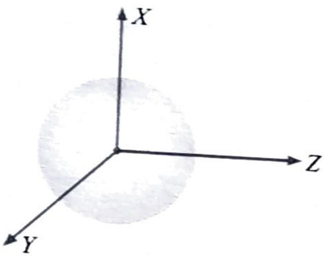
$\vec{p} = 0$, $E \propto \frac{1}{r^3}$ ∴ $E \propto \frac{1}{d^3}$

7. A certain charge distribution consists of two equivalent dipoles which are oppositely oriented. The leading term in the expansion of the potential is that due to a

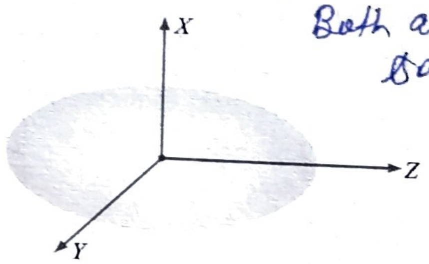
(a) Monopole (b) Dipole (c) Quadrupole (d) Octupole

8. A charge $-q$ is distributed uniformly over a sphere, with a positive charge q at its center in (i). Also in (ii), a charge $-q$ is distributed uniformly over an ellipsoid with a positive charge q at its center. With respect to the origin of the coordinate system, which one of the following statements is correct ?

Both are symmetric so p = 0 in both cases



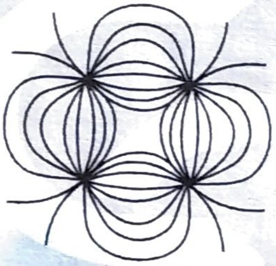
(i)



(ii)

(a) The dipole moment is zero in both (i) and (ii)
(b) The dipole moment is non-zero in (i) but zero in (ii)
(c) The dipole moment is zero in (i) but non-zero in (ii)
(d) The dipole moment is non-zero in both (i) and (ii)

9. The electrostatic lines of force due to a system of four point charges is sketched below.



At a large distance r, the leading asymptotic behaviour of the electrostatic potential is proportional to

(a) r (b) r^{-1} (c) r^{-2} (d) r^{-3} **[NET Dec. 2014]**

10. For an electric dipole with moment $\vec{p} = p_0\hat{e}_z$ placed at the origin, (p_0 is a constant of appropriate dimensions and $\hat{e}_x, \hat{e}_y$, and $\hat{e}_z$ are unit vectors in Cartesisn coordinate system)

(A) potential falls as $\frac{1}{r^2}$, where r is the distance from origin.

(B) a spherical surface centered at origin is an equipotential surface.

(C) electric flux through a spherical surface enclosing the origin is zero

(D) radial component of $\vec{E}$ is zero on the xy-plane.

11. Consider an electromagnetic wave at the interface between two homogeneouos dielectric media of the dielectric constants ε_1 and ε_2. Assuming $\varepsilon_2 > \varepsilon_1$ and non charges on the surface, the electric field vector E and the displacement vector $\vec{D}$ in the two media satisfy the following inequalities **[NET June 2014]**

(a) $|\vec{E}_2| > |\vec{E}_1|$ and $|\vec{D}_2| > |\vec{D}_1|$ (b) $|\vec{E}_2| < |\vec{E}_1|$ and $|\vec{D}_2| < |\vec{D}_1|$

(c) $|\vec{E}_2| < |\vec{E}_1|$ and $|\vec{D}_2| > |\vec{D}_1|$ (d) $|\vec{E}_2| > |\vec{E}_1|$ and $|\vec{D}_2| < |\vec{D}_1|$

12. Suppose *yz*-plane forms the boundary between two linear dielectric media *I* and *II* with dielectric constan $\varepsilon_I = 3$ and $\varepsilon_{II} = 4$, respectively. If the electric field in region. *I* at the interface is given by $\vec{E}_1 = 4\hat{x} + 3\hat{y} + 5\hat{z}$ then the electric field $\vec{E}_{II}$ at the interface in region *II* is:

(a) $4\hat{x} + 3\hat{y} + 5\hat{z}$ (b) $4\hat{x} + 0.75\hat{y} - 1.25\hat{z}$

(c) $-3\hat{x} + 3\hat{y} + 5\hat{z}$ (d) $3\hat{x} + 3\hat{y} + 5\hat{z}$

13. An infinite, conducting slab kept in a horizontal plane carries a uniform charge density σ. Another infinite slab of thickness *t*, made of a linear dielectric material of dielectric constant *k*, is kept above the conducting slab. The bound charge density on the upper surface of the dielectric slab is

(a) $\frac{\sigma}{2k}$ (b) $\frac{\sigma}{k}$ (c) $\frac{\sigma(k-2)}{2k}$ (d) $\frac{\sigma(k-1)}{k}$

14. Electric charges Q and –Q are distributed uniformly on the surfaces of two concentric shells of radii *a* and *b*, respectively ($a < b$). The energy required to assemble this charge distribution is

(a) $\frac{Q^2}{4\pi\varepsilon_0}\frac{(b-a)}{(b+a)^2}$ (b) $\frac{Q^2}{8\pi\varepsilon_0}\frac{(b-a)}{ab}$ (c) $\frac{Q^2}{4\pi\varepsilon_0}\frac{(b-a)}{b^2}$ (d) $\frac{Q^2}{8\pi\varepsilon_0}\frac{(b-a)}{b^2}$

Statement for Linked Answer Q. 15 and Q. 16 :

A dielectric sphere of radius R carries polarization $\vec{P} = kr^2\,\hat{r}$, wherer r is the distance from the centre and k is a constant. In the spherical polar coordinate system, $\hat{r}$, $\hat{\theta}$ and $\hat{\varphi}$ are the unit vectors.

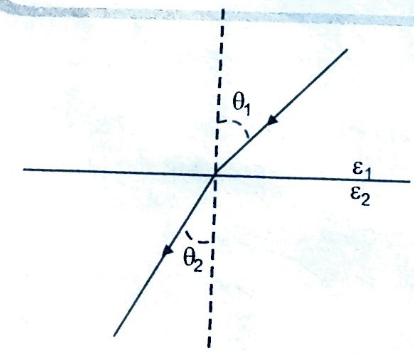
15. The bound volume charge density inside the sphere at a distance r from the centre is :

(a) –4kR (b) –4kr (c) $-4kr^2$ (d) $-4kr^3$ **[GATE 2006]**

16. The electric field inside the sphere at a distance d from the centre is : **[GATE 2006]**

(a) $\frac{-kd^2}{\varepsilon_0}\hat{r}$ (b) $\frac{-kR^2}{\varepsilon_0}\hat{r}$ (c) $\frac{-kd^2}{\varepsilon_0}\hat{\theta}$ (d) $\frac{-kR^2}{\varepsilon_0}\hat{\theta}$

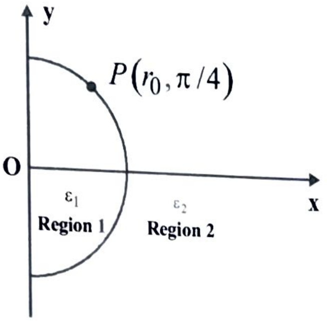
17. At the interface between two linear dielectrics (with dielectric constants (ε_1 and ε_2), the electric field lines bend, as shown in the figure. Assume that there are no free charges at the interface. The ratio ε_1 and ε_2 is :



(a) $\frac{\tan\theta_1}{\tan\theta_2}$ (b) $\frac{\cos\theta_1}{\cos\theta_2}$ (c) $\frac{\sin\theta_1}{\sin\theta_2}$ (d) $\frac{\cot\theta_1}{\cot\theta_2}$ **[GATE 2006]**

18. A ray of light insid Region 1 in the xy-plane is incident at the semicircle boundary that carries no free charges. The electric field at the point $P(r_0, \pi/4)$ in plane polar coordinates is $\vec{E}_1 = 7\hat{e}_r - 3\hat{e}_\varphi$, where $\hat{e}_r$ and $\hat{e}_\varphi$ are the unit vectors. The emerging ray in Region 2 has the electric field $\vec{E}_2$ parallel to x-axis. If ε_1 and ε_2 are the dielectric constants of Region 1 and Region 2 respectively, then $\frac{\varepsilon_2}{\varepsilon_1}$ is ________

[GATE 2014]



19. The space between the plates of a parallel plate capacitor is filled with two dielectric slabs of dielectric constants k_1 and k_2 as shown in the figure. If the capacitor is charged to a potential V, then at the interface between the two dielectrics.

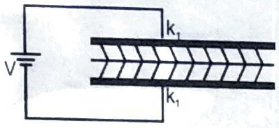
[GATE 2000]

(a) $\vec{E}$ is discontinuous and $\vec{D}$ is continuous

(b) $\vec{E}$ is discontinuous and $\vec{D}$ is discontinuous

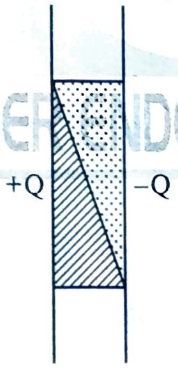
(c) $\vec{E}$ is continuous and $\vec{D}$ is continuous

(d) $\vec{E}$ is continuous and $\vec{D}$ is discontinous



20. The space between two plates of a capacitor carrying charges +Q and –Q is filled with two different dielectric materials, as shown in the figure. Across the interface of the two dielectric materials, which one of the following statements is correct?

[GATE 2015]



(a) $\vec{E}$ and $\vec{D}$ are continuous

(b) $\vec{E}$ is continuous and $\vec{D}$ is discontinuous

(c) $\vec{D}$ is continuous and $\vec{E}$ is discontinuous

(d) $\vec{E}$ and $\vec{D}$ are discontinuous

21. Two parallel plate capacitors, separated by distances x and $1.1x$ respectively, have a dielectric material of dielectric constant 3.0 inserted between the plates, and are connected to a battery of voltage V. The difference in charge on the second capacitor compared to the first is

[NET June 2016]

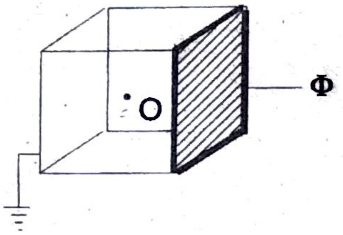
(a) $+66\%$ (b) $+20\%$ (c) -3.3% (d) -10%

22. A large charged copper sheet is surrounded by a dielectric medium of dielectric constant ϵ. At any po
on the flat surface of the sheet.

(a) The normal component of $\vec{E}$ is zero. (b) The normal component of $\vec{E}$ is not zero.

(c) The tangential component of $\vec{E}$ is zero. (d) The tangential component of $\vec{E}$ is not zero.

23. Five sides of a hollow metallic cube are grounded and the sixth side is insulated from the rest and is he
at a potential Φ (see figure). **[TIFR 2012]**



The potential at the centre O of the cube is

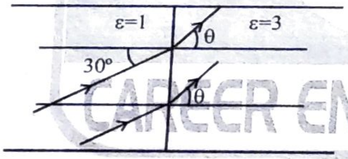
(a) 0 (b) $\Phi/6$ (c) $\Phi/5$ (d) $2\Phi/3$

24. A parallel plate capacitor of circular cross section with radius r >>d, where 'd' is the spacing between th
plates, is charged to a potential V and then disconnected from the charging circuit. If, now, the plates ar
slowly pulled apart (keeping then parallel) so that their separation is increased from d to d', the wor
done will be

(a) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\left(1-\frac{d'}{d}\right)$ (b) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\frac{d'}{d}$ (c) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\left(\frac{d'}{d}-1\right)$ (d) $\frac{\pi\varepsilon_0 r^2V^2}{2d}\frac{d}{d'}$ **[TIFR 2013]**

25. A cube has a constant electric potential V on its surface. If there are no charges inside the cube. the
potential at the center of the cube is **[JEST 2012]**
(a) V (b) V/8 (c) 0 (d) V/6

26. A large slab consists of two materials with dielectric constants 1 and 3 divided by a plane interface as shown in
the figure. An electric field exists in this slab, which uniformly makes an angle of 30° with the normal to th
interface on the left side of the $(\varepsilon = 1)$. The angle the field makes on the other side of the interface is:



(a) $\tan^{-1}(3)$ (b) $\sin^{-1}\left(\frac{1}{2\sqrt{3}}\right)$ (c) 60° (d) $\tan^{-1}(1/3)$

27. A dielectric sphere of radius R has constant polarization $\vec{P} = P_0\hat{z}$ so that the field inside the sphere is
$\vec{E}_{in} = -\frac{P_0}{3\epsilon_0}\hat{z}$. Then, which of the following is (are) correct?

$V = \frac{KP\cos\theta}{r^2}$

$= \frac{1}{4\pi\varepsilon_0}\frac{P\cdot\frac{4}{3}\pi R^3\cos\theta}{(2R)^2}$

$= \frac{P_0R}{12\varepsilon_0}$ (a, c, d)

(a) The bound surface charge density is $P_0\cos\theta$

(b) The electric field at a distance r on the z-axis varies as $\frac{1}{r^2}$ for $r \gg R$

(c) The electric potential at a distance 2R on the z-axis is $\frac{P_0R}{12\epsilon_0}$

(d) The electric field outside is equivalent to that of a dipole at the origin

28. An electric field applied along the length of a long cylinder produces a polarization P. The depolarization field produced in this configuration is : **[GATE 2003]**

(a) $4\pi P/3$ (b) $-4\pi P/3$ (c) $2\pi P$ (d) 0

29. A rectangular piece of dielectric material is inserted partially into the (air) gap between the plates of a parallel plate capacitor. The dielectric piece will **[NET Dec. 2017]**

(a) remain stationary where it is placed.

(b) be pushed out from the gap between the plates.

(c) be drawn inside the gap between the plates and its velocity does not change sign.

(d) execute an oscillatory motion in the region between the plates.

30. An atom of atomic number Z can be modelled as a point positive charge surrounded by a rigid uniformly negatively charged solid sphere of radius R. The electric polarisability α of this system is defined as

$$\alpha = \frac{p_E}{E}$$

where p_E is the dipole moment induced on application of electric field E which is small compared to the binding electric field inside the atom. It follows that $\alpha =$ **[TIFR 2018]**

(a) $\frac{8\pi\epsilon_0}{R^3}$ (b) $\frac{4\pi\epsilon_0}{R^3}$ (c) $8\pi\epsilon_0 R^3$ (d) $4\pi\epsilon_0 R^3$

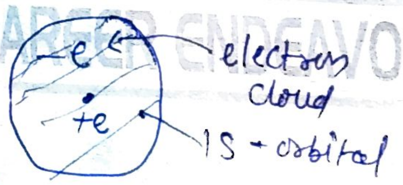
31. Two points charges $+2Q$ and $-Q$ are kept at points with Cartesian coordinates $(1, 0, 0)$ and $(2, 0, 0)$, respectively, in front of an infinite grounded conducting plate at $x = 0$. The potential at $(x, 0, 0)$ for $x \gg 1$ depends on x as **[NET June 2018]**

(a) x^{-3} (b) x^{-5} (c) x^{-2} (d) x^{-4}

32. Two conductors are embedded in a material of conductivity 10^{-4} S/m and dielectric constant $\epsilon = 80\,\epsilon_0$. The resistance between the two conductors is 10^6 ohm. What is the capacitance (in pF) between the conductors? Ignore the decimal part of the answer. **[JEST 2018]**

33. The intrinsic/permanent electric dipole moment in the ground state of hydrogen atom is (a_0 is the Bohr radius).

(a) $-3ea_0$ (b) zero (c) ea_0 (d) $3ea_0$ **[GATE 2018]**



origin is Symmetic so

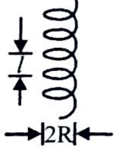
$\vec{p} = 0$

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-4 : Magnetostatics

1. A charged particle moves in a helical path under the influence of a constant magnetic field. The initial velocity is such that the component along the magnetic field is twice the component in the plane normal to the magnetic field. The ratio l/R of the pitch l to the radius R of the helical path is **[NET Dec. 2014]**



(a) $\pi/2$ (b) 4π

(c) 2π (d) π

2. Consider a region of space in which there are uniform electric and magnetic fields which are mutually parallel. A charged particle released from rest in this region will move in a

(a) straight line (b) circle (c) helix (d) cycloid

3. A charged particle in a uniform magnetic field $\vec{B} = B_0\hat{e}_z$ starts moving from the origin with velocity $\vec{v} = (3\hat{e}_x + 2\hat{e}_z)$ m/s. The trajectory of the particle and the time t at which it reaches 2 meters above the xy-plane are ($\hat{e}_x, \hat{e}_y$, and $\hat{e}_z$ are unit vectors in Cartesian - coordinate system.)

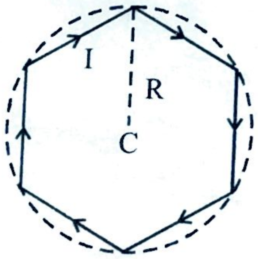
(a) Helical path; $t = 1s$ (b) Helical path; $t = 2/3s$

(c) Circular path; $t = 1s$ (d) Circular path; $t = 2/3s$

4. A proton moves with a speed of 300 m/s in a circular orbit in the xy-plane in a magnetic field 1 tesla along the positive z-direction. When an electric field of 1 V/m is applied along the positive y-direction, the center of the circular orbit **[NET June 2015]**

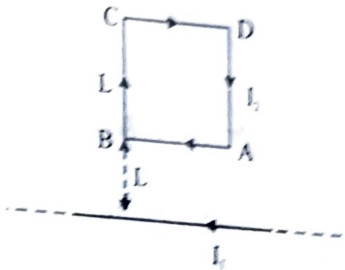
(a) remains stationary
(b) moves at 1 m/s along the negative x-direction
(c) moves at 1 m/s along the positive z-direction
(d) moves at 1 m/s along the positive x-direction

5. A conducting wire is in the shape of a regular hexagon, which is inscribed inside an imaginary circle of radius R, as shown. A current I flows through the wire. The magnitude of the magnetic field at the centre of the circle is



(a) $\dfrac{\sqrt{3}\mu_0 I}{2\pi R}$ (b) $\dfrac{\mu_0 I}{2\sqrt{3}\pi R}$ (c) $\dfrac{\sqrt{3}\mu_0 I}{\pi R}$ (d) $\dfrac{3\mu_0 I}{2\pi R}$

6. A rigid current-carrying square loop ABCD of side L is situated at a distance L from an infinite straight wire, with the side AB parallel to the latter, as shown in the figure below. The infinite wire, which is in the plane of the loop, carries a current I_1 from right to left, while the loop carries a current I_2 flowing clockwise.



The net force between thest two current-carryiing elements is

(a) repulsive of magnitude $\frac{3\mu_0}{4\pi}I_1I_2$ (b) repulsive of magnitude $\frac{\mu_0}{2\pi}I_1I_2$

(c) attractive of magnitude $\frac{3\mu_0}{2\pi}I_1I_2$ (d) zero (no net force)

7. Consider an infinitely long straight cylindrical conductor of radius R with its axis along the z-direction, which carries a current of 1 A uniformly distributed over its cross section. Which of the following statements is correct? **[GATE 2002]**

(a) $\vec{\nabla}\times\vec{B}=0$ everywhere (b) $\vec{\nabla}\times\vec{B}=\frac{\mu_0}{\pi R^2}\hat{z}$ everywhere

✓(c) $\vec{\nabla}\times\vec{B}=0$ for $r>R$ (d) $\vec{\nabla}\times\vec{B}=\frac{\mu_0}{\pi R^2}\hat{z}$ for $r>R$

where r is the radial distance from the axis of the cylinder.

8. If a charged particle of charge *q* and mass *m* moving with speed *v* enters a magnetic field ***B*** perpendicular to its direction of motion, it will move in a circular orbit of radius *R*. Then,

(a) *R* is directly proportional to *q*/*m* and |*B*|
(b) *R* is inversely proportional to *q*/*m* and |*B*|
(c) *R* is directly proportional to *q*/*m* and inversely proportional to |*B*|
(d) *R* is inversely proportional to *q*/*m* and directly proportional to |*B*|

9. The magnetic field at a distance R from a long straight wire carrying a steady current I is proportional to

(a) IR (b) I/R^2 (c) I^2/R^2 (d) I/R **[NET June 2012]**

10.✓ A long cylindrical kept along z-axis carries a current density $\vec{J}=J_0 r\hat{k}$, where J_0 is a constant and r is the radial distance form the axis of the cylinder. The magnetic induction $\vec{B}$ inside the conductor at a distance d from the axis of the cylinder is: **[GATE 2006]** $J = J_0 r^1 \hat{k}$

(a) $\mu_0 J_0\hat{\phi}$ (b) $\frac{\mu_0 J_0 d}{2}\hat{\phi}$ (c) $\frac{\mu_0 J_0 d^2}{3}\hat{\phi}$ (d) $\frac{\mu_0 J_0 d^3}{4}\hat{\phi}$

$B_{in} \propto r^2\hat{\phi}$
$B_{in} = d^2\hat{\phi}$ $r = d$

11. The magnetic field (in A m^{-1}) inside a long solid cylindrical conductor of radius a = 0.1 *m* is,

$H=\frac{10^4}{r}\left[\frac{1}{\alpha^2}\sin(\alpha r)-\frac{r}{\alpha}\cos(\alpha r)\right]\hat{\phi}$, where $\alpha=\frac{\pi}{2a}$. What is the total current (in A) in the conductor?

(a) $\frac{\pi}{2a}$ (b) $\frac{800}{\pi}$ (c) $\frac{400}{\pi}$ (d) $\frac{300}{\pi}$ **[GATE 2009]**

12. A short solenoid with n turns per unit length has diameter D and length L = 8D/15, as shown in the figure it carries a constant current I. The magnetic field B at a point P on the axis of the solenoid at a distance H 3 from its near end (see figure) is

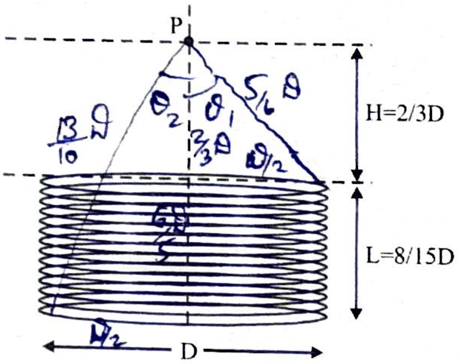
[TIFR 2014]

[use $\int dx\left(1+x^2\right)^{-3/2} = x\left(1+x^2\right)^{-1/2}$]

$B = \frac{\mu_0 n I}{2}\left(\cos\theta_1 + \cos\theta_2\right)$

$\cos\theta_1 = \frac{2/3}{5/6} = \frac{4}{5}$

$\cos\theta_2 = \frac{6/5}{13/10} = \frac{12}{13}$



(a) $\frac{4}{65}\mu_0 nI$ (b) $\frac{4}{13}\mu_0 nI$ (c) $\frac{24}{15}\mu_0 nI$ (d) $\frac{112}{65}\mu_0 nI$

13. A very long solenoid with n turns per unit length carries a current I. The magnetic field at a point, which is on its axis and its end face, is :

(a) $\mu_0 nI$ (b) $(2/3)\mu_0 nI$ (c) $(1/3)\mu_0 nI$ (d) $(1/2)\mu_0 nI$

14. **STATEMENT I :**

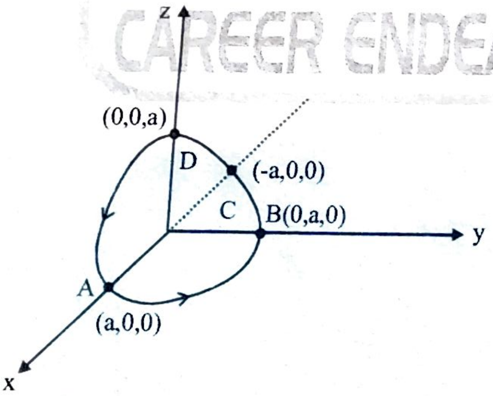
The work done by the magnetic force on a moving charged particle is zero.

STATEMENT II :

The magnetic force tends to change the direction of a moving charged particle in a direction perpendicular to both the magnetic field and the instantaneous velocity of the particle.

(a) Statements I and II both are ture. Statement II is the correct explanation for statement I.
(b) Statements I and II both are true. Statement II is not the correct explanation for statement I.
(c) Statement I is true but statement II is false.
(d) Statement I is false but statement II is true

15. In the following figure, ABC and CDA are two semicircular conducting wires of radius a with the origin as their common centre. The arc ABC lies on the xy-plane whereas CDA lies on the xz-plane. They are joined as shown. This combined loop carries a current in the direction indicated in the figure below. Which of the following unit vectors denotes the direction of the resulting magnetic field vector at the origin?



(a) $(1,0,0)$ (b) $\left(0,\frac{1}{\sqrt{2}},\frac{1}{\sqrt{2}}\right)$ (c) $\left(\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}\right)$ (d) $(-1,0,0)$

16. A particle of mass m carrying charge q is moving in a circle in a magnetic field B. According to Bohr's model. the energy of the particle in the n^{th} level is

(a) $\frac{1}{n^2}\left(\frac{hqB}{\pi m}\right)$ (b) $n\left(\frac{hqB}{\pi m}\right)$ (c) $n\left(\frac{hqB}{2\pi m}\right)$ (d) $n\left(\frac{hqB}{4\pi m}\right)$

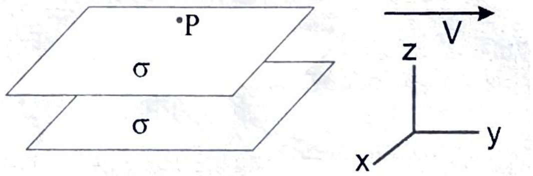
17. A ring of radius R carries a linear charge density λ. It is rotating with angular speed ω. The magnetic field at its centre is

(a) $\frac{3\mu_0\lambda\omega}{2}$ (b) $\frac{\mu_0\lambda\omega}{2}$ (c) $\frac{\mu_0\lambda\omega}{\pi}$ (d) $\mu_0\lambda\omega$

18. Magnetic induction $|B|$ due to current I in a coil of radius R placed in y-z plane at a distance X along the axis of the coil is given by $\frac{\mu_0 I}{2}\frac{R^2}{\left(R^2+X^2\right)^{3/2}}$. Another similar coil of radius R, carrying equal current I is placed in the y-z plane at a distance 2R from the first coil along the same axis. The value of $|B|$ at a point midway between the two coils and on the x-axis is:

(a) $\frac{\mu_0 I}{2\sqrt{2}\,R}$ (b) $\frac{\mu_0 I\,R}{2\sqrt{2}}$ (c) 0 (d) $\frac{\mu_0 I}{4\sqrt{2}\,R}$

19. Two large parallel plates move with a constant speed v in the positive y-direction as shown in the figure. If both the plates have a surface charge density $\sigma > 0$, the magnetic field at the point P just above the top plate will have :



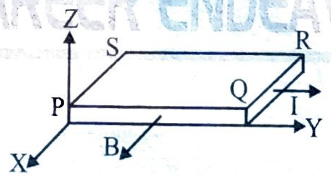
(a) Larger magnitude than the field at the mid-point between the plates and point towards $-\hat{x}$

(b) Smaller magnitude than the field at the mid-point between the plates and point towards $+\hat{x}$.

(c) Larger magnitude than the field at the mid-point between the plates and point towards $+\hat{x}$

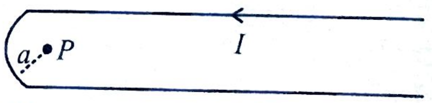
(d) Smaller magnitude than the field at the mid-point between the plates and point towards $-\hat{x}$

20. A conducting slab of copper PQRS is kept on the *xy* plane in a uniform magnetic field along *x*-axis as indicated in the figure. A steady current *I* flows through the cross section of the slab along the *y*-axis. The direction of the electric field inside the slab, arising due to the applied magnetic field is along the



(a) negative Y direction
(b) positive Y direction
(c) negative Z direction
(d) positive Z direction

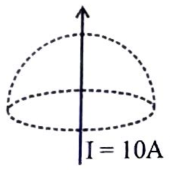
21. An infinite conducting wire, which is bent in the shape of a hairpin (the curved part being a semicircle of radius a = 1cm) as shown in the figure, carries a unit current



(a) 1.3 gauss (b) 7.1 gauss (c) 0.82 gauss (d) 0.51 gauss

22. A current $I = 10A$ flows in an infinitely long wire along the axis of a hemisphere (see figure). The value

$\int (\vec{\nabla} \times \vec{B}) \cdot d\vec{s}$ over the hemispherical surface as shown in the figure is

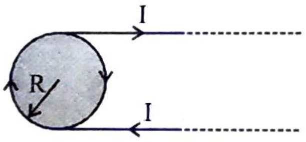


(a) $10\mu_0$ (b) $5\mu_0$ (c) 0 (d) $7.5\mu_0$

23. Consider a thin long insulator coated conducting wire carrying current I. It is now wound once aroun an insulating thin disc of radius R to bring the wire back on the same side, as shown in the figure. Th magnetic field at the centre of the disc is equal to:

(a) $\frac{\mu_0 I}{2R}$ (b) $\frac{\mu_0 I}{4R}\left[3+\frac{2}{\pi}\right]$

(c) $\frac{\mu_0 I}{4R}\left[1+\frac{2}{\pi}\right]$ (d) $\frac{\mu_0 I}{2R}\left[1+\frac{1}{\pi}\right]$



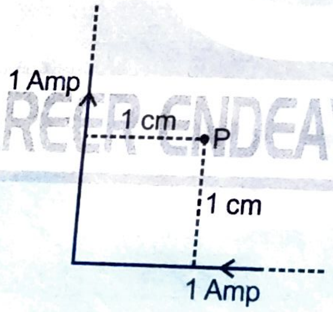
24. A straight beam of ultrarelativistic electrons, confined within a very long cylindrical region of radius less than mm, carries a current of 0.01 μA. The strength of the electric field at a point 2 cm away from the beam axis wi be nearest to

[Hint : Calculate the charge per unit length from the given information].

(a) 6×10^{-5} V/m (b) 1×10^{-4} V/m (c) 3×10^{-5} V/m

(c) 2×10^{-3} V/m (d) 8×10^{-4} V/m

25. Consider a L-shaped conductor carrying a current of 1 Ampere, as shown in the figure. Assume that both th arms extended to infinity. The strength of the magnetic field at the point P, which is at a distance of 1 cm fron both the arms, is nearest to



(a) 1.2×10^{-7} T (b) 3.4×10^{-5} T (c) 6.9×10^{-6} T

(d) 4.3×10^{-4} T (e) 2.1×10^{-5} T

Net 2016

26. A set N concentric circular loops of wire, each carrying a steady current I in the same direction, is arranged in a plane. The radius of the first loop is $r_1 = a$ and the radius of the n^{th} loop is given by $r_n = n\,r_{n-1}$. The magni- tude B of the magnetic field at the centre of the circles in the limit $N \to \infty$, is

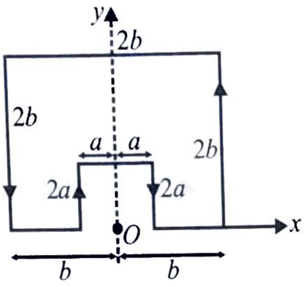
(a) $\frac{\mu_0 I(e^2-1)}{4\pi a}$ (b) $\frac{\mu_0 I(e-1)}{\pi a}$ (c) $\frac{\mu_0 I(e^2-1)}{8a}$ (d) $\frac{\mu_0 I(e-1)}{2a}$

27. A constant current I is flowing in a piece of wire that is bent into a loop as shown in the figure.

$B_1 \propto \frac{1}{a}$, $B_2 \propto \frac{1}{b}$

$\therefore B = B_1 - B_2$

$B \propto \left(\frac{1}{a} - \frac{1}{b}\right)$



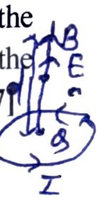
The magnitude of the magnetic field at the point O is **[NET June 2017]**

(a) $\frac{\mu_0 I}{4\pi\sqrt{5}} \ln\left(\frac{a}{b}\right)$ (b) $\frac{\mu_0 I}{4\pi\sqrt{5}} \ln\left(\frac{1}{a} - \frac{1}{b}\right)$ (c) $\frac{\mu_0 I}{4\pi\sqrt{5}}\left(\frac{1}{a}\right)$ (d) $\frac{\mu_0 I}{4\pi\sqrt{5}}\left(\frac{1}{b}\right)$

28. A proton of kinetic energy 1880 MeV in a circular orbit in a plane perpendicular to a uniform magnetic field of strength 5 Tesla. What is the radius of the orbit ?

(a) 75.6 m [✓ (b)] 3.1 m (c) 5.3 m (d) 1.8 m (e) 24.3 m

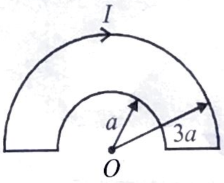
29. A circular current carrying loop of radius a carries a steady current. A constant electric charge is kept at the centre of the loop. The electric and magnetic fields, $\vec{E}$ and $\vec{B}$ respectively, at a distance d vertically above the centre of the loop satisfy **[NET Dec. 2017]**



$\vec{E} \times \vec{B} = 0$

(a) $\vec{E} \perp \vec{B}$ (b) $\vec{E} = 0$ (c) $\vec{\nabla}\left(\vec{E}\cdot\vec{B}\right) = 0$ [✓ (d)] $\vec{\nabla}\cdot\left(\vec{E}\times\vec{B}\right) = 0$

30. The loop shown in the figure below carries a steady current I. **[NET June 2018]**



The magnitude of the magnetic field at the point O is

(a) $\frac{\mu_0 I}{2a}$ [✓ (b)] $\frac{\mu_0 I}{6a}$ (c) $\frac{\mu_0 I}{4a}$ (d) $\frac{\mu_0 I}{3a}$

31. An infinitely long straight wire is carrying a steady current I. The ratio of magnetic energy density at distance r_1 to that at $r_2 (= 2r_1)$ from the wire is ________. **[GATE 2018]**

CAREER ENDEAVOUR

Best Institute for IIT-JAM, NET & GATE

CSIR-UGC-NET/JRF | GATE-PHYSICS

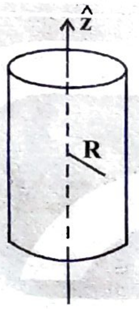
ELECTROMAGNETIC THEORY

Assignment-5 : Vector Potential and Magnetisation

1. For constant uniform electric and magnetic fields $\vec{E} = \vec{E}_0$ and $\vec{B} = \vec{B}_0$, it is possible to choose a gauge such that the scalar potential ϕ and vector potential $\vec{A}$ are given by **[NET June 2011]**

(a) $\phi = 0$ and $\vec{A} = \frac{1}{2}(\vec{B}_0 \times \vec{r})$
(b) $\phi = -\vec{E}_0.\vec{r}$ and $\vec{A} = \frac{1}{2}(\vec{B}_0 \times \vec{r})$
(c) $\phi = -\vec{E}_0.\vec{r}$ and $\vec{A} = 0$
(d) $\phi = 0$ and $\vec{A} = -\vec{E}_0 t$

2. ✓ An infinite solenoid with its axis of symmetry along the z-direction carries a steady current I.



R-distance
$A_{in} \propto R$
$A_{out} \propto \frac{1}{R}$

The vector potential $\vec{A}$ at a distance R from the axis. **[NET Dec. 2012]**
(a) Is constant inside and varies as R outside the solenoid.
(b) Varies as R inside and is constant outside the solenoid.
(c) Varies as 1/R inside and as R outside the solenoid.
✓(d) Varies as R inside and as 1/R outside the solenoid.

3. The vector potential $\vec{A}$ due to a magnetic moment 'm' at a point 'r' is given by $\vec{A} = \frac{\vec{m} \times \vec{r}}{r^3}$. If $\vec{m}$ is directed along the positive z-axis, the x-component of the magnetic field, at the point r, is **[NET June 2012]**

(a) $\frac{3myz}{r^5}$
(b) $-\frac{3mxy}{r^5}$
✓(c) $\frac{3mxz}{r^5}$
(d) $\frac{3m(z^2 - xy)}{r^5}$

✓ 4. The magnetic field corresponding to the vector potential, $\bar{A} = \frac{1}{2}\bar{F} \times \bar{r} + \frac{10}{r^3}\bar{r}$ where $\bar{F}$ is a constant vector, is

let $\vec{F} = F\hat{i}$

(a) $\bar{F}$
(b) $-\bar{F}$
(c) $\bar{F} + \frac{30}{r^4}\bar{r}$
(d) $\bar{F} - \frac{30}{r^4}\bar{r}$ **[NET June 2012]**

5. A thin infinitely long solenoid placed along the z-axis contains a magnetic flux ϕ. Which of the following vector potentials corresponds to the magnetic field at an arbitrary point (x, y, z)? **[NET June 2014]**

(a) $(A_x, A_y, A_z) = \left(-\frac{\phi}{2\pi}\frac{y}{x^2+y^2}, \frac{\phi}{2\pi}\frac{x}{x^2+y^2}, 0\right)$

(b) $\left(A_x, A_y, A_z\right)=\left(-\frac{\phi}{2\pi}\frac{y}{x^2+y^2+z^2}, \frac{\phi}{2\pi}, \frac{x}{x^2+y^2+z^2}, 0\right)$

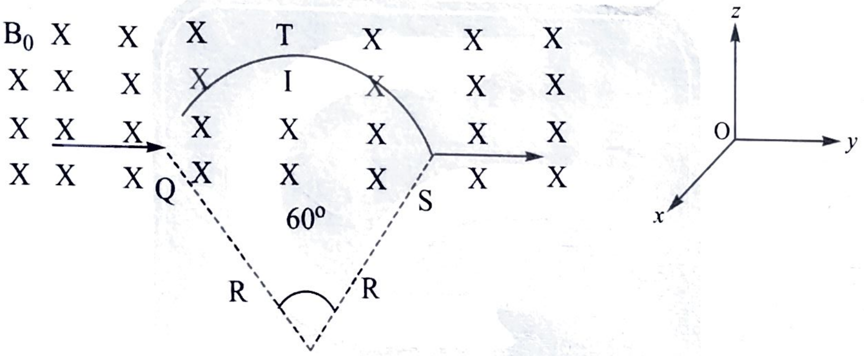
(c) $\left(A_x, A_y, A_z\right)=\left(-\frac{\phi}{2\pi}\frac{x+y}{x^2+y^2}, \frac{\phi}{2\pi}, \frac{x}{x^2+y^2}, 0\right)$

(d) $\left(A_x, A_y, A_z\right)=\left(-\frac{\phi}{2\pi}\frac{x}{x^2+y^2}, \frac{\phi}{2\pi}, \frac{y}{x^2+y^2}, 0\right)$

6. A current I flows in the anticlockwise direction through a square loop of side a lying in the xoy plane with its center at the origin. The magnetic induction at the center of the square loop is : **[GATE 2001]**

(a) $\frac{2\sqrt{2}\mu_0 I}{\pi a}\hat{e}_x$ (b) $\frac{2\sqrt{2}\mu_0 I}{\pi a}\hat{e}_z$ (c) $\frac{2\sqrt{2}\mu_0 I}{\pi a^2}\hat{e}_z$ (d) $\frac{2\sqrt{2}\mu_0 I}{\pi a^2}\hat{e}_x$

7. A circular arc QTS is kept in an external magnetic field $\vec{B}_0$ as shown in figure. The arc carries a current I. The magnetic field is directed normal and into the page. The force acting on the arc is : **[GATE 2014]**



(a) $2IB_0\hat{k}R$ (b) $IB_0R\hat{k}$ (c) $-2IB_0R\hat{k}$ (d) $-IB_0R\hat{k}$

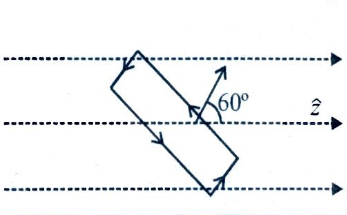
8. The value of $\oint_c \vec{A}\cdot d\vec{\ell}$ along a square loop of side L in a uniform field $\vec{A}$ is : **[GATE 2006]**

(a) 0 (b) 2LA (c) 4LA (d) L^2A

9. ✓ Which of the following expressions for a vector potential $\vec{A}$ **DOES NOT** represent a uniform magnetic field of magnitude B_0 along the z-direction? **[GATE 2011]**

(a) $\vec{A}=(0, B_0x, 0)$ (b) $\vec{A}=(-B_0y, 0, 0)$ (c) $\vec{A}=\left(\frac{B_0x}{2}, \frac{B_0y}{2}, 0\right)$ (d) $\vec{A}=\left(-\frac{B_0y}{2}, \frac{B_0x}{2}, 0\right)$

10. In a constant magnetic field of 0.6 Tesla along the z direction, find the value of the path integral $\oint \vec{A}\cdot\vec{dl}$ in the units of (Tesla m²) on a square loop of side length $(1/\sqrt{2})$ meters. The normal to the loop makes an angle of 60° to the z-axis, as shown in the figure. The answer should be up to two decimal places. ____



[GATE 2013]

11. A toroidal coil has N closely-wound turns. Assume the current through the coil to be I and the toroid is filled with a magnetic material of relative permittivity μ_r. The magnitude of magnetic induction $\vec{B}$ inside the toroid, at a radial distance r from the axis, is given by **[GATE 2007]**

(a) $\mu_r\mu_0 NIr$ (b) $\frac{\mu_r\mu_0 NI}{r}$ (c) $\frac{\mu_r\mu_0 NI}{2\pi r}$ (d) $2\pi\mu_r\mu_0 NIr$

12. The vector potential of a moving charge is dependent upon

(a) Its velocity only (b) Its charge only (c) Its momentum (d) Its velocity and charge

13. The magnitude of vector potential at a point $r\,(r < R)$ in an infinite solenoid with N-turns per unit length, radius R and carrying a current I, is given by

(a) $A = \mu_0 N I r^2$ (b) $A = \frac{\mu_0 N I r^2}{2}$ (c) $A = \mu_0 N I r$ (d) $A = \frac{\mu_0 N I r}{2}$

14. The expression $\vec{A} = \frac{B}{2}\left(-\hat{i}y + \hat{j}x\right)$ for the vector potential represents

(a) a uniform magnetic field in the z-direction (b) a non-uniform magnetic field in the z-direction
(c) a uniform magnetic field in xy-plane (d) a non-uniform magnetic field in xy-plane

15. A dipole of moment $\vec{p}$, oscillating at frequency ω, radiates spherical waves. The vector potential at large distance is $\vec{A}(\vec{r}) = \frac{\mu_0}{4\pi} i\omega \frac{e^{ikr}}{r}\vec{p}$. To order $(1/r)$ the magnetic field $\vec{B}$ at a point $\vec{r} = r\hat{n}$ is

(a) $-\frac{\mu_0}{4\pi}\frac{\omega^2}{c}(\hat{n}\cdot\vec{p})\hat{n}\frac{e^{ikr}}{r}$ (b) $-\frac{\mu_0}{4\pi}\frac{\omega^2}{c}(\hat{n}\times\vec{p})\frac{e^{ikr}}{r}$ **[NET Dec. 2015]**

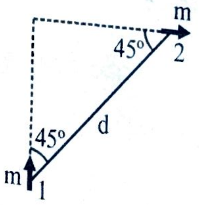
(c) $-\frac{\mu_0}{4\pi}\omega^2 k(\hat{n}\cdot\vec{p})\vec{p}\frac{e^{ikr}}{r}$ (d) $-\frac{\pi_0}{4\pi}\frac{\omega}{c}\vec{p}\frac{e^{ikr}}{r}$

16. A current carrying loop lying in the plane of the paper is in the shape of an equilateral triangle of side a. It carries a current I in the clockwise sense. If $\hat{k}$ denotes the outward normal to the plane of the paper, the magnetic moment $\vec{m}$ due to the current loop is: **[NET 2008]**

(a) $\vec{m} = a^2 I\,\hat{k}$ (b) $\vec{m} = -\frac{1}{2}a^2 I\,\hat{k}$ (c) $\vec{m} = \frac{\sqrt{3}}{2}a^2 I\,\hat{k}$ (d) $\vec{m} = -\frac{\sqrt{3}}{2}a^2 I\,\hat{k}$

17. The magnitude of the magnetic dipole moment associated with a square shaped loop carrying a steady current I is m. If this loop is changed to a circular shape with the same current I passing through it, the magnetic dipole moment becomes $\frac{pm}{\pi}$. The value of p is ________

18. Two magnetic dipoles of magnitude m each are placed in a plane as shown



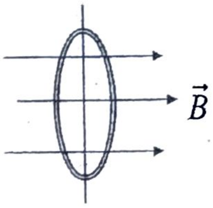
The energy of interaction is given by

(a) Zero (b) $\frac{\mu_0}{4\pi}\frac{m^2}{d^3}$ (c) $\frac{3\mu_0}{2\pi}\frac{m^2}{d^3}$ (d) $\frac{3\mu_0}{8\pi}\frac{m^2}{d^3}$ **[GATE 2010]**

19. A circular coil of radius 120 mm with 10 turns is placed with its plane parallel to the earth's magnetic field. When a current of 0.45 A flows through the coil, a compass needle placed at the center of the coil is seen to be deflected by an angle of 45° to the plane of the coil. The intensity of the earth's magnetic field is calculated to be

(a) 0.3 μT (b) 24 μT (c) 42 μT (d) 100 μT

20. A loop of wire of radius a and carrying a current I is suspended vertically in a uniform horizontal magnetic field B as shown. Calculate the work done in rotating the loop around the vertical axis through an angle π



(a) $\frac{\pi^2 I^2 B}{2a}$ (b) $2\pi a^2 IB$ (c) $\frac{\pi a^2 IB}{2}$ (d) 0

21. A small magnetic needle is kept at (0, 0) with its moment along the x-axis. Another small magnetic needle is at the point (1, 1) and is free to rotate in the xy-plane. In equilibrium the angle θ between their magnetic moments is such that **[NET Dec. 2015]**

(a) $\tan\theta = 1/3$ (b) $\tan\theta = 0$ (c) $\tan\theta = 3$ (d) $\tan\theta = 1$

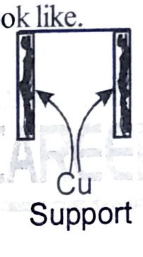
22. A spherical shell of radius R carries a constant surface charge density σ and is rotating about one of its diameters with an angular velocity ω. The magnitude of the magnetic moment of the shell is: **[JEST 2016]**

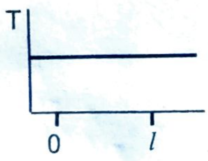
(a) $4\pi\sigma\omega R^4$ (b) $4\pi\sigma\omega R^4/3$ (c) $4\pi\sigma\omega R^4/15$ (d) $4\pi\sigma\omega R^4/9$

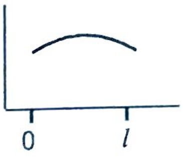
23. For the magnetic field measurement, Gauss-meters employ the principle of

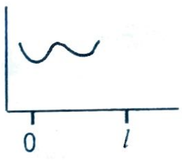
(a) double exchange (b) super exchange (c) Jahn-Teller effect (d) Hall effect

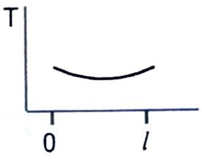
24. A tungsten wire of uniform cross section and high resistance is supported by two copper supports of low resistance in vacuum. The length of the wire is l. A constant current I is sent through the wire. The temperature profile (T vs. x) of the wire will look like.



(a)


(b)


(c)


(d)


25. The x-y plane is the boundary between free space and a magnetic material with relative permeability μ_r. The magnetic field in the free space is $B_x\hat{i} + B_z\hat{k}$. The magnetic field in the magnetic material is **[GATE 2016]**

(a) $B_x\hat{i} + B_z\hat{k}$ (b) $B_x\hat{i} + \mu_r B_z\hat{k}$

(c) $\frac{1}{\mu_r}B_x\hat{i} + B_z\hat{k}$ (d) $\mu_r B_x\hat{i} + B_z\hat{k}$

26. A small magnetic dipole is kept at the origin in the x-y plane. One wire L_1 is located at z = –a in the x-z plan with a current I flowing in the positive x direction. Another wire L_2 is at z = +a in y-z plane with the same curren I as in L_1, flowing in the positve y direction. The angle φ made by the magnetic dipole with respect to th positive x-axis is:

(a) 225° (b) 120° (c) 45° (d) 270°

mean Circular

27. A loop of radius *a*, carrying a current *I*, is placed in a uniform magnetic field ***B***. If the normal to the loop is denoted by $\hat{n}$, the force ***F*** and the torque ***T*** on the loop are **[NET June 2016]**

∵ $\vec{B}$ = uniform & wire is closed loop $\vec{F} = 0$

(a) $\boldsymbol{F} = 0$ and $\boldsymbol{T} = \pi a^2 I\,\hat{n} \times \boldsymbol{B}$

(b) $\boldsymbol{F} = \frac{\mu_0}{4\pi} I \times \boldsymbol{B}$ and $\boldsymbol{T} = 0$

(c) $\boldsymbol{F} = \frac{\mu_0}{4\pi} I \times \boldsymbol{B}$ and $\boldsymbol{T} = I\,\hat{n} \times \boldsymbol{B}$

(d) $\boldsymbol{F} = 0$ and $\boldsymbol{T} = \frac{1}{\mu_0 \varepsilon_0} I\boldsymbol{B}$

$$\vec{\tau} = \int I\, d\vec{s} \times \vec{B}$$
$$= \int I\, ds\, \hat{n} \times \vec{B}$$
$$= I \pi a^2 \hat{n} \times \vec{B}$$

ⓐ

28. A constant and uniform magnetic field $\vec{B} = B_0\,\hat{k}$ prevades all space. Which one of the following is the correc choice for the vector potential in Coulomb gauge? **[GATE 2018]**

(a) $-B_0\,(x+y)\,\hat{i}$ (b) $B_0\,(x+y)\,\hat{j}$ (c) $B_0 x\hat{j}$ (d) $-\frac{1}{2}B_0\,(x\hat{i} - y\hat{j})$

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-6 : Electromagntic Theory

1. The magnetic flux density in a region is given by $B = \left(2\hat{i} + 3\hat{j} - 4\hat{k}\right)e^{-2t}\,\text{Wb/m}^2$. A square loop of 2m side is placed in the region, with its center at the origin and its sider along the co-ordinate axes. The emf induced in the loop at t = 1 sec is
(a) 1.35 volts (b) 3.24 volts (c) 4.33 volts (d) 5.41 volts

2. A uniform magnetic field in the positive *z*-direction passes through a circular wire loop of radius 1 cm and resistance 1 Ω lying in the *xy*-plane. The field strength is reduced from 10 tesla to 9 tesla in 1 s. The charge transferred across any point in the wire is approximately **[NET June 2015]**
(a) 3.1×10^{-4} coulomb (b) 3.4×10^{-4} coulomb
(c) 4.2×10^{-4} coulomb (d) 5.2×10^{-4} coulomb

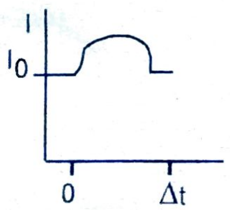
3. A long solenoid is embedded in a conducting medium and is insulated from the medium. If the current through the solenoid is increased at a constant rate, the induced current in the medium as a function of the radial distance *r* from the axis of the solenoid is proportional to **[GATE 2015]**
(a) r^2 inside the solenoid and $\frac{1}{r}$ outside (b) r inside the solenoid and $\frac{1}{r^2}$ outside
(c) r^2 inside the solenoid and $\frac{1}{r^2}$ outside (d) r inside the solenoid and $\frac{1}{r}$ outside

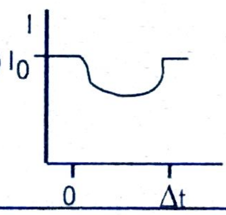
4. A small loop of wire of area $A = 0.01\ \text{m}^2$, N = 40 turns and resistance $R = 20\Omega$ is initially kept in a uniform magnetic field B in such a way that the field is normal to the plane of the loop. When it is pulled out of the magnetic field, a total charge of $Q = 2\times10^{-5}\,C$ flows through the coil. The magnitude of the field B is:
(a) $1\times10^{-3}\,T$ (b) $4\times10^{-3}\,T$
(c) Zero (d) Unobtainable, as the data is insufficient

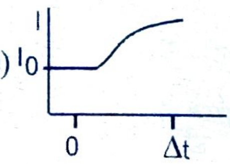
5. A metal rod AB rotates clockwise in the plane of the paper about the end B with an angular velocity ω in a uniform magnetic field emerging out of the plane of the paper normally. The end B about which the rod rotates will be
(a) Positive with respect to the end A
(b) Negative with respect to the end A.
(c) Having same potential as the remaining part of the rod.
(d) Having same potential as the end B, but the centre of the rod will be at higher potential.

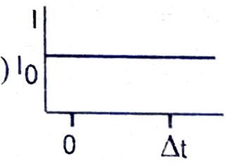
6. A solenoid with an iron core is connected in series with a battery of emf V and it is found that a constant current I_0 passes through the solenoid. If at t = 0, the iron core is pulled out from the solenoid quickly in a time Δt, which one of the following could be a correct description of the current passing through the solenoid?

[GATE 2000]

(a) 

(b) 

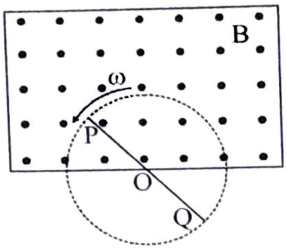
(c) 

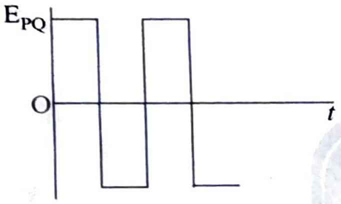
(d) 

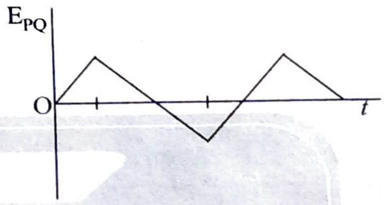
7. A circular conducting ring of radius 'R' rotates with constant angular velocity ω about its diameter plac along the x-axis. A uniform magnetic field B is applied along the y-axis. If at time $t=0$ the ring is entirely in th xy- plane, the emf induced in the ring at time $t>0$ is **[JEST 2012]**

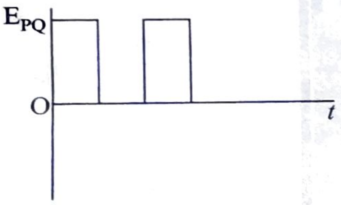
(a) $B\omega^2\pi R^2 t$ (b) $B\omega\pi R^2\tan(\omega t)$ (c) $B\omega\pi R^2\sin(\omega t)$ (d) $B\omega\pi R^2\cos(\omega t)$

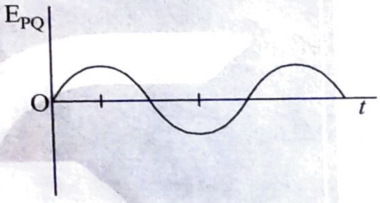
8. A uniform and costant magnetic field B coming out of the plane of the paper exists in a rectangular region a shown in the figure. A conducting rod PQ is rotated about O with a uniform angular speed ω in the plane of th paper. The emf E_{PQ} induced between P and Q is best represented by the graph.



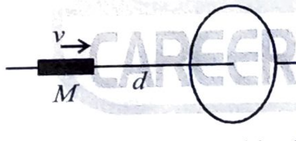
(a)


(b)


(c)


(d)


9. A bar magnet, of magnetic moment M, is moving with a constant velocity v along the axis of a circular coil o radius R. The direction of the magnetic moment of the bar magnet is parallel to its velocity as shown in the figur below



What is the magnitude of the e.m.f. induced in the coil at an instant when the magnet is at a distance d (wher $d>>R$) from it?

(a) $\frac{\mu_0 R^2 Mv}{2d^3}$ (b) $\frac{3\mu_0 R^2 Mv}{2d^4}$ (c) $\frac{\mu_0 R^2 Mv}{4d^2}$ (d) $\frac{\mu_0 R^2 Mv}{4d^4}$ (e) $\frac{3\mu_0 R^2 Mv}{4d^3}$

10. A rod of length L with uniform charge density λ per unit length is in the xy-plane and rotating about z-axi passing through one of its edge with an angular velocity $\vec{\omega}$ as shown in the figure below. $(\hat{r},\hat{\phi},\hat{z})$ refer to th unit vectors at Q, $\vec{A}$ is the vector potential at a distance d from the origin O along z-axis for $d>>L$ and $\vec{J}$ is th current density due to the motion of the rod. **[GATE 2008]**

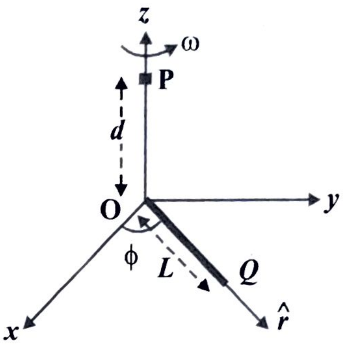
Which one of the following statements is correct?

(a) $\vec{J}$ along $\hat{r}$; $\vec{A}$ along $\hat{z}$; $|\vec{A}|\propto\frac{1}{d}$

(b) $\vec{J}$ along $\hat{\phi}$; $\vec{A}$ along $\hat{\phi}$; $|\vec{A}| \propto \frac{1}{d^2}$

(c) $\vec{J}$ along $\hat{r}$; $\vec{A}$ along $\hat{z}$; $|\vec{A}| \propto \frac{1}{d^2}$

(d) $\vec{J}$ along $\hat{\phi}$; $\vec{A}$ along $\hat{\phi}$; $|\vec{A}| \propto \frac{1}{d}$



11. A magnetic field $\boldsymbol{B}$ is $B\hat{z}$ in the region $x > 0$ and zero elsewhere. A rectangular loop, in the *xy*-plane, of sides l (along the *x*-direction) and h (along the y-direction) is inserted into the $x > 0$ region from the $x < 0$ region at a constant velocity $\mathbf{v} = v\hat{x}$. Which of the following values of l and h will generate the largest EMF ?

[NET June 2016]

(a) $l = 8,\ h = 3$ (b) $l = 4,\ h = 6$ (c) $l = 6,\ h = 4$ (d) $l = 12,\ h = 2$

12. A thin and straight metallic rod of length L is rotating about its middle point with angular velocity ω in a uniform magnetic field of strength B. The axis of rotation is perpendicular to the length of the rod and parallel to the direction of the magnetic field. The strength of the induced electric field is

(a) constant throughout the rod

(b) maximumat the two points halfway between the centre and the two ends

(c) minimum at the two points halfway between the centre and the two ends

(d) maximum at the ends and minimum at the centre.

Statement for linked Answer Q.13 and Q.14:

An infinitely long hollow cylinder of radius R carrying a surface charge density s is rotated about its cylinderical axis with a constant angular speed w

13. The magnitude of the surface current is :

[GATE 2005

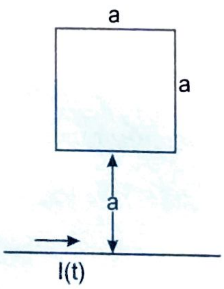
(a) $\sigma R\omega$ (b) $2\sigma R \omega$ (c) $\pi \sigma R \omega$ (d) $2 \pi \sigma R \omega$

14. The magnitude of vector potential inside the cylinder at a distance from its axis is : **[GATE 2005]**

(a) $2\mu_0\sigma R\omega r$ (b) $\mu_0\sigma R\omega r$ (c) $\frac{1}{2}\mu_0\sigma R\omega r$ (d) $\frac{1}{4}\mu_0\sigma R\omega r$

15. An infinitely long wire carrying a current $I(t) = I_0 \cos(wt)$ is placed at a distance a from a square loop of side a as shown in the figure. If the resistance of the loop is R, then the amplitude of the induced current in the loop is :

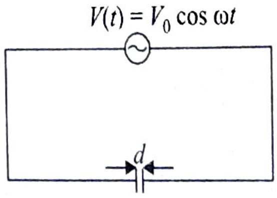
[GATE 2005]



(a) $\frac{\mu_0}{2\pi}\frac{aI_0\omega}{R}\ln 2$ (b) $\frac{\mu_0}{\pi}\frac{aI_0\omega}{R}\ln 2$

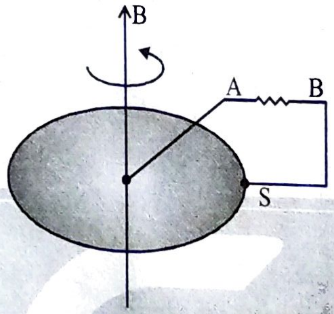
(c) $\frac{2\mu_0}{\pi}\frac{aI_0\omega}{R}\ln 2$ (d) $\frac{\mu_0}{2\pi}\frac{aI_0\omega}{R}$

16. An oscillating voltage $V(t) = V_0 \cos\omega t$ is applied across a parallel plate capacitor having a plate separati
The displacement current density through the capacitor is:



(a) $\frac{\varepsilon_0 \omega V_0 \cos\omega t}{d}$ (b) $\frac{\varepsilon_0 \mu_0 \omega V_0 \cos\omega t}{d}$ (c) $-\frac{\varepsilon_0 \mu_0 \omega V_0 \sin\omega t}{d}$ (d) $-\frac{\varepsilon_0 \omega V_0 \sin\omega t}{d}$

17. A horizontal metal disc rotates about the vertical axis in a uniform magnetic field pointing up as shown in th figure. A circuit is made by connecting one end A of a resistor to the centre of the disc and the other end B its edge through a sliding contact S. The current that flows through the resistor is



(a) zero
(b) DC from A to B **[NET Dec. 2013]**
(c) DC from B to A
(d) AC

18. The condition that the magnetic field $\vec{B}$ is a curl of a vector potential $\vec{A}$ should be

(a) $\vec{\nabla}.B = 0$ (b) $\vec{\nabla} \times \vec{A} = 0$ (c) $\vec{\nabla}\vec{A} = 0$ (d) $\vec{\nabla} \times \vec{A} - \nabla^2 \vec{A} = 0$

19. The magnetic field $\vec{B}$ can be expressed in terms of the vector potential as $\vec{B} = \vec{\nabla} \times \vec{A}$. If $\vec{B} = B\hat{k}$ then $\vec{A}$ ca be expressed as

(a) $\left(-\frac{1}{2}By, \frac{1}{2}Bx, 0\right)$ (b) $\left(\frac{1}{2}By, -\frac{1}{2}Bx, 0\right)$ (c) $(0, 0, B)$ (d) $\left(\frac{Bx}{3}, \frac{By}{3}, \frac{Bz}{3}\right)$

20. An infinitely long closely would solenoid carries a sinusoidally varying current. The induced electric field is:
(a) Zero everywhere
(b) Non-zero inside and zero outside the solenoid
(c) Non-zero inside as well as outside the solenoid
(d) Zero inside and non-zero outside the solenoid

21. A time-dependent magnetic field $\vec{B}(t)$ is produced in a circular region of space, infinitely long and of radius R. The magnetic field is given as $\vec{B} = B_0 t\hat{z}$ for $0 \le r < R$ and is zero for $r > R$. Where B_0 is a positive constant. The electric field for $r > R$ is

[JEST 2012]

(a) $\frac{B_0 R^2}{r}\hat{r}$ (b) $\frac{B_0 R^2}{2r}\hat{\theta}$ (c) $-\frac{B_0 R^2}{r}\hat{r}$ (d) $-\frac{B_0 R^2}{2r}\hat{\theta}$

22. A conducting loop L of surface area S is moving with a velocity $\vec{\upsilon}$ in a magnetic field $\vec{B}(\vec{r},t)=\vec{B}_0 t^2$, B_0 is a positive constant of suitable dimensions. The emf induced, V_{emf}, in the loop is given by: **[GATE 2009]**

(a) $-\int_S \frac{\partial \vec{B}}{\partial t}.d\vec{S}$ (b) $\oint_L (\vec{\upsilon}\times\vec{B}).d\vec{L}$

(c) $-\int_S \frac{\partial \vec{B}}{dt}.d\vec{S}-\oint_L (\vec{\upsilon}\times\vec{B}).d\vec{L}$ (d) $-\int_S \frac{\partial \vec{B}}{dt}.d\vec{S}+\oint_L (\vec{\upsilon}\times\vec{B}).d\vec{L}$

23. Which one of the following Maxwell's equations implies the absence of magnetic monopoles?

(a) $\nabla.E=\pi/\varepsilon_0$ (b) $\nabla.B=0$ **[GATE 2003]**

(c) $\nabla\times E=-\partial B/\partial t$ (d) $\nabla\times B=\left(1/c^2\right)\partial B/\partial t+\mu_0 J$

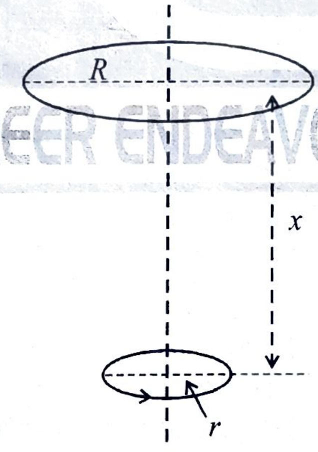
24. A large circular coil of N turns and radius R carries a time varying current $i=i_0\sin(wt)$. A small circular coil of n turns and radius r (r<<R) is placed at the center of the large coil such that the coils are concentric and coplanar. The induced emf in the small coil

(a) Leads the current in the large coil by $\pi/2$ **[GATE 2002]**
(b) Lags the current in the large coil by π
(c) Is in phase with the current in the large coil
(d) lags the current in the large coil by $\pi/2$

25. Self inductance per unit length of a long solenoid of radius *R* with *n* turns per unit length is:

(a) $\mu_0\pi R^2 n^2$ (b) $2\mu_0\pi R^2 n$ (c) $2\mu_0\pi R^2 n^2$ (d) $\mu_0\pi R^2 n$

26. Consider the following system. Two circular loops of wire are placed horizontally, having a common axis passing vertically through the centre of each coil (see figure). The lower loop has radius 'r' and carries a current 'i' as shown in the figure. The upper loop has a radius $R(R>>r)$ and is at a distance $x(x>>R)$ above it.



If the lower loop is held fixed and the upper loop moves upwards with a uniform velocity $v=\frac{dx}{dt}$, then the induced e.m.f. and the direction of the induced current in this loop will be

(a) $3i\mu_0\pi^2 r^2 R^2 v/2x^4$; anti-clockwise (b) $2i\mu_0\pi^2 r^2 R^2 v/2x^4$; clockwise

(c) $3i\mu_0\pi^2 r^2 R^2 v/2x^3$; anti-clockwise (d) $2i\mu_0\pi^2 r^2 R^2 v/2x^3$; clockwise

27. Current flowing in a circuit containing a capacitor. To satisfy the continuity equation, $\vec{\nabla}.\vec{J} = -\frac{\partial\rho}{\partial t}$ for and current, the current density $\vec{J}$ must be replaced by

(a) $\frac{1}{4\pi}\frac{\partial\vec{D}}{\partial t}$ (b) $\vec{J}-\frac{1}{4\pi}\frac{\partial\vec{D}}{\partial t}$ (c) $\vec{D}+\frac{1}{4\pi}\frac{\partial\vec{J}}{\partial t}$ (d) $\vec{J}+\frac{1}{4\pi}\frac{\partial\vec{D}}{\partial t}$

28. A charge capacitor (C) is connected in series with an inductor (L). When the displacement current re zero, the energy of the LC circuit is **[GATE 2007]**

(a) stored entirely in its magnetic field

(b) stored entirely in its electric field

(c) distributed equally among its electric and magnetic fields.

(d) radiated out of the circuit.

29. A plane electromagnetic wave is propagating in a lossless dielectric. The electric field is gi $E(x,y,z,t)=E_0(\hat{x}+A\hat{z})\exp\left[ik_0\left\{-ct+\left(x+\sqrt{3z}\right)\right\}\right]$, where c is the speed of light in vacuum, E_0, k_0 are constants and $\hat{x}$ and $\hat{z}$ are unit vectors along the x- and z-axes. The relative dielectric constant medium, ε_r and the constant A are **[NET June 201**

(a) $\varepsilon_r = 4$ and $A = -\frac{1}{\sqrt{3}}$ (b) $\varepsilon_r = 4$ and $A = +\frac{1}{\sqrt{3}}$

(c) $\varepsilon_r = 4$ and $A = \sqrt{3}$ (d) $\varepsilon_r = 4$ and $A = -\sqrt{3}$

30. A conducting circular loop is placed in a uniform magnetic field B = 0.04 T with its plane perpendicular field. Somehow the radius of the loop starts shrinking at a constant rate of 0.5 mm/sec. The induced emf loop at an instant, when the radius is 2cm, will be

(a) 5.0 μV (b) 2.5 μV (c) 10.0 μV (d) 25.0 μV

31. A linearly polarized electromagnetic wave is incident on a quarter wave plate. The emerge wave general be

(a) linearly polarized

(b) elliptically polarized

(c) unpolarized

(d) mixture of linearly polarized and unpolarized wave

32. The magnitude of the Poynting vector gives the

(a) energy transported per unit area per unit time

(b) energy density of the electromagnetic wave

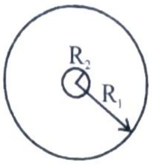
(c) angular momentum density of the electromagnetic wave

(d) angular momentum transported per unit area per unit time

33. A parallel plate capacitor is formed by two circular conducting plates of radius a separated by a distance where $d \ll a$. It is being slowly charged by a current that is nearly constant. At an instant when the current I, the magnetic induction between the plates at a distance $a/2$ from the centre of the plate, is

(a) $\frac{\mu_0 I}{\pi a}$ (b) $\frac{\mu_0 I}{2\pi a}$ (c) $\frac{\mu_0 I}{a}$ (d) $\frac{\mu_0 I}{4\pi a}$ **[NET Dec. 2016]**

34. Consider two, single turn, co-planar, concentric coils of radii R_1 and R_2 with $R_1 \gg R_2$. The mutual inductance between the two coils is proportional to



(a) R_1 / R_2 (b) R_2 / R_1 (c) R_2^2 / R_1 (d) R_1^2 / R_2

35. Consider a circular parallel plate capacitor of radius R with separation d between the plates $(d \ll R)$. The plates are placed symmetrically about the origin. If a sinusoidal voltage $V = V_0 \sin \omega t$ is applied between the plates, which of the following statement (s) is (are) true?

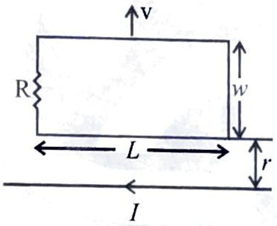
(a) The maximum value of the Poynting vector at $r = R$ is $\frac{V_0^2 \epsilon_0 \omega R}{4d^2}$

(b) The average energy per cycle flowing out of the capacitor is zero

(c) The magnetic field inside the capacitor is constant

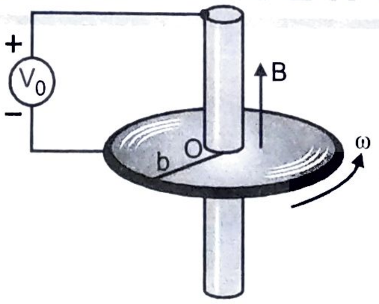
(d) The magnetic field lines inside the capacitor are circular with the curl being independent of r

36. A rectangular loop of dimension L and width w moves with a constant velocity v away from an infinitely long straight wire carrying a current I in the plane of the loop as shown in the figure below. Let R be the resistance of the loop. What is the current in the loop at the instant the near-side is at a distance r from the wire?



(a) $\frac{\mu_0 IL}{2\pi R} \frac{wv}{r[r+2w]}$ (b) $\frac{\mu_0 IL}{2\pi R} \frac{wv}{r[2r+w]}$ (c) $\frac{\mu_0 IL}{2\pi R} \frac{wv}{r[r+w]}$ (d) $\frac{\mu_0 IL}{2\pi R} \frac{wv}{2r[r+w]}$

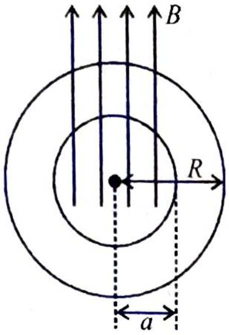
37. A circular metal disk (Faraday disk generator) is rotating with a constant angular velocity ω in a uniform and constant magnetic field of flux density $\vec{B} = \hat{a}_z B_0$ that is parallel to the axis of rotation. Determine the open-circuit voltage (V_0) of the generator if the radius of the disk is b.



(a) $-\frac{\omega B_0 b^2}{2}$ (b) $\frac{\omega B_0 b^2}{2}$ (c) $\frac{\pi \omega B_0 b^2}{2}$

(d) $\pi \omega B_0 b^2$ (e) $-\frac{\omega B_0 b^2}{2\pi}$

38. A wire carrying line-charge density λ is converted into a circular loop of radius R. Then it is suspended hori
tally (with non-conducting spokes) so that it is free to rotate in the horizontal plane. A uniform magnetic field
is applied in the central region (pointing up) out to radius $a (R > a)$. The angular momentum imparted to
loop when the field is turned is given by



(a) $\pi B a^2$ (b) 0 (c) $\pi R^2 \lambda a$ (d) $\pi \lambda a^2 R B$

(e) $\pi B \lambda^2$

39. Two parallel rails of a railroad track are insulated from each other and from the ground. The distance betw
the rails is 1 meter. A voltmeter is electrically connected between the rails. Assume the vertical component
the earth's magnetic field to be 0.2 gauss. What is the voltage developed between the rails when a train tra
at a speed of 180 km/h along the track? Give the answer in milli-volts. **[JEST 201**

40. Consider an infinitely long solenoid with N turns per unit length, radius R and carrying a current $I(t) = \alpha$ cos
where α is a constant and ω is the angular frequency. The magnitude of electric field at the surface of
solenoid is **[GATE 20**

(a) $\frac{1}{2}\mu_0 N R \omega \alpha \sin \omega t$ (b) $\frac{1}{2}\mu_0 \omega N R \cos \omega t$ (c) $\mu_0 N R \omega \alpha \sin \omega t$ (d) $\mu_0 \omega N R \cos \omega t$

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-7 : Electromagntic Theory

1. Consider the interference of two coherent electromagnetic waves whose electric field vectors are given by $\vec{E}_1 = \hat{i}E_0 \cos\omega t$ and $\vec{E}_2 = \hat{j}E_0 \cos(\omega t + \varphi)$ where φ is the phase difference. The intensity of the resulting wave is given by $\frac{\varepsilon_0}{2}\langle E^2\rangle$, where $\langle E^2\rangle$ is the time average of E^2. The total intensity is **[NET Dec. 2012]**

(a) 0 (b) $\varepsilon_0 E_0^2$ (c) $\varepsilon_0 E_0^2 \sin^2\varphi$ (d) $\varepsilon_0 E_0^2 \cos^2\varphi$

2. The electric field of an electromagnetic wave is given by $\vec{E} = E_0 \cos[\pi(0.3x + 0.4y - 1000t)]\hat{k}$. The associated magnetic field $\vec{B}$ is **[NET Dec. 2013]**

(a) $10^{-3} E_0 \cos[\pi(0.3x + 0.4y - 1000t)]\hat{k}$ (b) $10^{-4} E_0 \cos[\pi(0.3x + 0.4y - 1000t)](4\hat{i} - 3\hat{j})$

(c) $E_0 \cos[\pi(0.3x + 0.4y - 1000t)](0.3\hat{i} + 0.4\hat{j})$ (d) $10^{2} E_0 \cos[\pi(0.3x + 0.4y - 1000t)](3\hat{i} + 4\hat{j})$

3. An electromagnetically-shielded room is designed so that at a frequency $\omega = 10^7$ rad/s the intensity of the external radiation that penerates the room is 1% of the incident radiation. If $\sigma = \frac{1}{2\pi} \times 10^6 (\Omega m)^{-1}$ is the conductivity of the shielding material, its minimum thickness should be (given that ln 10 = 2.3) **[NET June 2014]**

(a) 4.60 mm (b) 2.30 mm (c) 0.23 mm (d) 0.46 mm

4. The electric field E(r, t) at a point r at time t in a metal due to the passage of electrons can be described by the equation **[GATE 2001]**

$$\nabla^2\vec{E}(\vec{r},t) = \frac{1}{c^2}\left[\frac{\partial^2\vec{E}(\vec{r},t)}{\partial t^2} + \omega'^2\vec{E}(\vec{r},t)\right]$$

Where ω' is a characteristic frequency associated with the metal and c is the speed of light in vacuum. The dispersion relation corresponding to the plane wave solutions of the form $\exp\left[i\left(\vec{k}.\vec{r} - \omega t\right)\right]$ is given by:

(a) $\omega^2 = c^2k^2 - \omega'^2$ (b) $\omega^2 = c^2k^2 + \omega'^2$ (c) $\omega^2 = ck - \omega'$ (d) $\omega = ck + \omega'$

5. The state of polarization of light with the electric field vector **[GATE 2004]**

$\vec{E} = \hat{i}E_0 \cos(kz - \omega t) - \hat{j}E_0 \cos(kz - \omega t)$ is:

(a) Linearly polarized along z-direction
(b) Linearly polarized at –45° to x-axis
(c) Circularly polarized
(d) Elliptically polarized with the major axis along x- axis

Data for Q. 6 and Q. 7.

Consider two conducting plates of infinite extent, one plate at $z = 0$ and the other at $z = L$, both parallel to th xy plane. The vector and scalar potential in the region between the plates is given by :

$A(r,t) = A_0\, i \cos(kz + \alpha)\cos(kct);\ \phi(r,t) = 0$

6. For this to represent a standing wave in the empty region between the plates : **[GATE 2003]**

(a) $k = \pi / L$ and $\alpha = 0$ (b) $k = 2\pi / L$ and $\alpha = \pi / 2$

(c) $k = \pi / (2L)$ and $\alpha = \pi / 2$ (d) $k = \pi / 2L$ and $\alpha = 0$

7. The energy density at $z = 0$ and $t = 0$ is : **[GATE 2003]**

(a) 0 (b) $\varepsilon_0 c^2 k^2 A_0^2$

(c) $(1/2)\mu_0 A_0^2 k^2$ (d) $(1/2)\mu_0 A_0^2 k^2 + (1/2)\varepsilon_0 c^2 k^2 A_0^2$

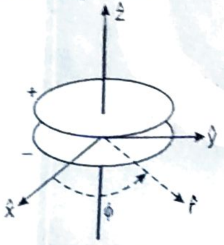
8. Consider the given statements about E(r, t) and B(r, t), the electric and magnetic vectors respectively in a regio of free space **[GATE 2003]**

P. Both E and B are conservative vector fields
Q. Both E and B are central force fields
R. E and B are mutually perpendicular in the region
S. Work done by B on a moving charge in the region is zero

Choose the right combination of correct statements from the following :

(a) P and R (b) R and S (c) S only (d) P and Q

9. A parallel plate capacitor is being discharged. What is the direction of the energy flow in terms of the poyntin vector in the space betwen the plates? **[GATE 2008]**



(a) Along the wire in the positive z axis (b) Radially inward $(-\hat{r})$

(c) Radially outward $(\hat{r})$ (d) Circumferential (ϕ)

10. A plane electromagnetic wave is given by $E_0(\hat{x} + e^{i\delta}\hat{y})\exp\{i(kz - \omega t)\}$. At a given location, the number o times $\vec{E}$ vanishes in one second is : **[GATE 2008]**

(a) An integer near $\frac{\omega}{\pi}$ when $\delta = n\pi$ and zero when $\delta \neq n\pi$, n is integer

(b) An integer near $\frac{\omega}{\pi}$ and is independent of δ

(c) An integer near $\frac{\omega}{2\pi}$ when $\delta = n\pi$ and zero when $\delta \neq n\pi$, n is integer

(d) An integer near $\frac{\omega}{2\pi}$ and is independent of δ

Statement for Linked Answer Q. 11 and Q. 12.

Consider the propagation of electromagnetic waves in a linear, homogenous and isotropic material mediu with electric permitivity ε, and magnetic permeability μ.

11. For a plane wave of angular frequency ω and propagation vector $\vec{k}$ propagating in the medium Maxwell's equations reduce to **[GATE 2010]**

(a) $\vec{k}.\vec{E}=0; \vec{k}.\vec{H}=0; \vec{k}\times\vec{E}=\omega\varepsilon\vec{H}; \vec{k}\times\vec{H}=-\omega\mu\vec{E}$

(b) $\vec{k}.\vec{E}=0; \vec{k}.\vec{H}=0; \vec{k}\times\vec{E}=-\omega\varepsilon\vec{H}; \vec{k}\times\vec{H}=\omega\mu\vec{E}$

(c) $\vec{k}.\vec{E}=0; \vec{k}.\vec{H}=0; \vec{k}\times\vec{E}=-\omega\mu\vec{H}; \vec{k}\times\vec{H}=\omega\varepsilon\vec{E}$

(d) $\vec{k}.\vec{E}=0; \vec{k}.\vec{H}=0; \vec{k}\times\vec{E}=\omega\mu\vec{H}; \vec{k}\times\vec{H}=-\omega\varepsilon\vec{E}$

12. If ε and μ assume negative values in a certain frequency range, then the directions of the propagation vector $\vec{k}$ and the Poynting vector $\vec{S}$ in that frequency range are related as

(a) $\vec{k}$ and $\vec{S}$ are parallel

(b) $\vec{k}$ and $\vec{S}$ are anti-parallel. **[GATE 2010]**

(c) $\vec{k}$ and $\vec{S}$ are perpendicular to each other

(d) $\vec{k}$ and $\vec{S}$ make an angle that depends on the magnitude of $|\varepsilon|$ and $|\mu|$.

13. The electric field of a uniform plane wave propagating in a dielectric, non-conducting medium is given by,

$$\vec{E}=\hat{x}10\cos\left(6\pi\times10^{7}\,t-0.4\pi z\right)V/m$$

The phase velocity of the wave is ________ $\times10^{8}$ m/s.

[GATE 2014]

14. An electromagnetic wave with $\vec{E}(z,t)=E_0\cos(\omega t-kz)\hat{i}$ is travelling in free space and crosses a disc of radius 2m placed perpendicular to the z-axis. If $E_0=90V\ m^{-1}$, the average power, in watt, crossing the disc along the z-direction is

[GATE 2007]

(a) 30 (b) 60 (c) 120 (d) 135

15. The magnetic field associated with the electric field vector $\vec{E}=E_0\sin(kz-\omega t)\hat{j}$ is given by

(a) $\vec{B}=-\frac{E_0}{c}\sin(kz-\omega t)\hat{i}$ (b) $\vec{B}=\frac{E_0}{c}\sin(kz-\omega t)\hat{i}$

(c) $\vec{B}=\frac{E_0}{c}\sin(kz-\omega t)\hat{j}$ (d) $\vec{B}=\frac{E_0}{c}\sin(kz-\omega t)\hat{k}$

16. For a medium of electric and magnetic field the relation between E and B with propagation vector k

(a) $\bar{E}\times\bar{k}=\omega\bar{B}$ (b) $\bar{E}\times\bar{R}=\bar{\omega}\times\bar{B}$ (c) $\bar{E}=\frac{k}{\omega}\times\bar{B}$ (d) $\bar{B}=\frac{k\times\bar{E}}{\omega}$

17. The electric field of two linearly polarized waves are given by $\vec{E}_1=\hat{i}E_x\cos(\omega t-\theta_1)$ and $\vec{E}_2=\hat{j}E_y\cos(\omega t-\theta_2)$. The nature of polarization of the superimposed wave is :

(a) Unpolarized (b) Linearly polarized

(c) Circularly polarized (d) Elliptically polarized

18. In a free space, which is the correct set of Maxwell's equations in absence of any charges and current densities

(a) $\vec{\nabla}.\vec{E}=\rho/\varepsilon_0, \vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}$

$\vec{\nabla}.\vec{B}=0, \vec{\nabla}\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$

(b) $\vec{\nabla}.\vec{E}=0, \vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}$

$\vec{\nabla}.\vec{B}=0, \vec{\nabla}\times\vec{B}=\mu_0\vec{J}$

(c) $\vec{\nabla}.\vec{E}=\rho/\varepsilon_0, \vec{\nabla}\times\vec{E}=0$

$\vec{\nabla}.\vec{B}=0, \vec{\nabla}\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$

(d) $\vec{\nabla}.\vec{E}=0, \vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}$

$\vec{\nabla}.\vec{B}=0. \vec{\nabla}\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$

19. Three plane waves are given as $\bar{y}_1 = A_1\,\hat{y}.\cos(kx-\omega t+\delta_1)$, $\bar{y}_2 = A_2\,\hat{z}\cos(kx-\omega t+\delta_2)$ $\bar{y}_3 = A_3\,\hat{y}\cos(kx-\omega t+\delta_3)$, where $\delta_1, \delta_2, \delta_3$ and A_1, A_2, A_3 are constants. If these waves are superposed pairwise, which superposition will lead to interference?

(a) $\bar{y}_1$ and $\bar{y}_2$ (b) $\bar{y}_2$ and $\bar{y}_3$ (c) $\bar{y}_1$ and $\bar{y}_3$ (d) No interference in any pair

20. A 1W point source at origin emits light uniformly in all the directions. If the units for both the axes ar measured in centimetre, then the Poynting vector at the point (1, 1, 0) in W/cm^2 is

($\hat{e}_x, \hat{e}_y$, and $\hat{e}_z$ are unit vectors in Cartesian - coordinate system.)

(a) $\frac{1}{8\pi\sqrt{2}}(\hat{e}_x+\hat{e}_y)$ (b) $\frac{1}{16\pi}(\hat{e}_x+\hat{e}_y)$ (c) $\frac{1}{16\pi\sqrt{2}}(\hat{e}_x+\hat{e}_y)$ (d) $\frac{1}{4\pi\sqrt{2}}(\hat{e}_x+\hat{e}_y)$

21. An electromagnetic wave is elliptically polarized in the X-Y plane. The direction of the Poynting vector is in th

(a) Z-direction (b) X-direction (c) Y-direction (d) XY-plane

22. Which of the following proposed space-time dependent electric fields in vacuum is/are allowed by the equations of electromagnetic theory?

(I) $E_x = E_1\sin(kz-\omega t)$, $E_y = E_2\sin(kz-\omega t)$, $E_z = 0$

(II) $E_x = E_1\sin(kz-\omega t)$, $E_y = 2E_2\cos(kz-\omega t)$, $E_z = 0$

(III) $E_x = E_1\sin(kz-\omega t)$, $E_y = 0$, $E_z = E_2\sin(kz-\omega t)$

[In the above E_1 and E_2 are real constants]

(a) I and II but not III (b) II and III but not I
(c) I and III but not II (d) I only (e) I, II and III

23. The poynting vector in the radial direction, at the surface of a long straight wire, of radius b and resistance per unit length R, carrying a current I is:

(a) $\frac{-RI^2}{2\pi b}\hat{r}(\text{inward})$ (b) $\frac{RI^2}{2\pi b}\hat{r}(\text{outward})$

(c) $\frac{bI}{2\pi R}\hat{r}(\text{inward})$ (d) $\frac{2\pi I}{Rb}\hat{r}(\text{inward})$

24. A medium with refractive index $n(\omega)$, where ω is the frequency, is said to posses anomalous dispersion when

(a) $\frac{\partial n}{\partial\omega} > 0$ (b) $\frac{\partial n}{\partial\omega} < 0$ (c) $\frac{\partial^2 n}{\partial\omega^2} > 0$ (d) $\frac{\partial^2 n}{\partial\omega^2} < 0$

25. In a non-magnetic dielectric medium with dielectric constant $\varepsilon_r = 4$, the electric field of a propagating plane wave with $\omega = 10^8$ rad/s is given by, $\vec{E} = (-\hat{i}+\sqrt{3}\hat{j})\exp[j(\omega t-\vec{k}.\vec{r})]$. The propagation vector $\vec{k}$ (in units of m^{-1}) is given by

(a) $\vec{k} = \frac{1}{\sqrt{3}}\hat{i}+\frac{1}{3}\hat{j}$ (b) $\vec{k} = \frac{1}{3}\hat{z}$ (c) $\vec{k} = \frac{1}{2\sqrt{3}}\hat{i}+\frac{1}{6}\hat{j}$ (d) $\vec{k} = -\frac{1}{\sqrt{3}}\hat{i}+\frac{1}{3}\hat{j}$

26. Two beams of light with electric field amplitudes $\hat{i}E$ and $(\hat{i}-2\hat{j})E$ interfere at a point with path difference $\lambda/2$. The magnitude of the electric field at the point of interference is

(a) $2\sqrt{2}$ E (b) 0 (c) 2 E (d) $(1+\sqrt{5})$E

27. In a region of space it is found that $\vec{\nabla}.\vec{E}=0$ but $\vec{\nabla}\times\vec{E}\neq 0$. Which of the following statements is not true?
(a) The charge density must be zero
(b) A displacement current must exist
(c) The divergence of magnetic field must be zero
(d) A time-varying magnetic field must exist

28. A microwave source of wave length $\lambda = 3$ cm is used in a double slit interference experiment. The distance D from the slits to the detector is 1m. If the distance d between the slits increases from 1mm to 5 cm, then
(a) the fringes being to overlap
(b) the central maximum becomes more intense
(c) the secondary sources at the slits lose coherence
(d) the separation between the maxima decreases.

29. The skin depth of a metal is dependent on the conductivity (σ) of the metal and the angular frequency ω of the incident field. For a metal of high conductivity, which of the following relations is correct ? (Assume that $\sigma \gg \varepsilon\omega$, where ε is the electrical permittivity of the medium). **[JEST 2015]**

(a) $d \propto \sqrt{\sigma/\omega}$ (b) $d \propto \sqrt{1/\sigma\omega}$ (c) $d \propto \sqrt{\sigma\omega}$ (d) $d \propto \sqrt{\omega/\sigma}$

30. The wavelength of red helium-neon laser in air is 6328 Å. What happens to its frequency in glass that has a refractive index of 1.50 ? **[JEST 2015]**

(a) Increases by a factor of 3 (b) Decreases by a factor of 1.5
(c) Remains the same (d) Decreases by a factor of 0.5

31. A monochromatic plane wave (wavelength = 600 nm) $E_0\exp[i(kz-\omega t)]$ is incident normally on a diffraction grating giving rise to a plane wave $E_1\exp\left[i\left(\vec{k}_1\cdot\vec{r}-\omega t\right)\right]$ in the first order of diffraction. Here $E_1 < E_0$ and $\vec{k}_1 = \left|\vec{k}_1\right|\left[\frac{1}{2}\hat{x}+\frac{\sqrt{3}}{2}\hat{z}\right]$. The period (in μm) of the diffraction grating is________(upto one decimal place)

32. The electric field $\vec{E}(\vec{r},t)$ for a circularly polarized electromagnetic wave propagating along the positive z direction is : **[GATE 2005]**

(a) $E_0(\hat{x}+\hat{y})\exp[i(kz-\omega t)]$ (b) $E_0(\hat{x}+i\hat{y})\exp[i(kz-\omega t)]$
(c) $E_0(\hat{x}+i\hat{y})\exp[i(kz+\omega t)]$ (d) $E_0(\hat{x}+\hat{y})\exp[i(kz+\omega t)]$

33. A plane electromagnetic wave is travelling along the positive z-direction. The maximum electric field along the x-direction is 10 V/m. The approximate maximum values of the power per unit area and the magnetic induction B, respectively, are **[NET June 2015]**
(a) 3.3×10^{-7} watts/m^2 and 10 tesla (b) 3.3×10^{-7} watts/m^2 and 3.3×10^{-8} tesla
(c) 0.265 watts/m^2 and 10 tesla (d) 0.265 watts/m^2 and 3.3×10^{-8} tesla

34. A beam of unpolarized light in a medium with dielectric constant $\in_1$ is reflected from a plane interface formed with another medium of dielectric constant $\in_2 = 3\in_1$. The two media have identical magnetic permeability. If the angle of incidence is 60°, then the reflected light
(a) is plane polarized perpendicular to the plane of incidence
(b) is plane polarized parallel to the plane of incidence
(c) is circularly polarized
(d) has the same polarization as the incident light.

35. At 'equilibrium' there can not be any free charge inside a metal. However, if you forcibly put charg in the interior then it takes some finite time to 'disappear', *i.e.* move to the surface. If the conductivi σ, of a metal is $10^6(\Omega\, m)^{-1}$ and the dielectric constant $\in_0 = 8.85\times10^{-12}$ Farad/m, this time will b approximately: **[JEST 2013]**

(a) 10^{-5} sec (b) 10^{-11} sec (c) 10^{-9} sec (d) 10^{-17} sec

36. The electric field of an electromagnetic wave is given by $\vec{E} = \hat{i}E_0\sin(ky-\omega t)$, where '$k$' and ω respectivel denote the wave vector and angular frequency of the wave. $\hat{i}$, $\hat{j}$ and $\hat{k}$ respectively denote the unit vectors i the x, y and z directions. The magnetic field $\vec{B}$ of the wave is given by

(a) $\hat{k}E_0 k\sin(ky-\omega t)$ (b) $\hat{j}E_0\cos(ky-\omega t)$

(c) $-\hat{k}\dfrac{E_0\omega}{k}\cos(ky-\omega t)$ (d) $-\hat{k}\dfrac{E_0\omega}{k}\sin(ky-\omega t)$

37. How much force does light from a 1.8 W laser exert when it is totally absorbed by an object?

(a) $6.0\times10^{-9}N$ (b) $0.6\times10^{-9}N$ (c) $6.0\times10^{-8}N$ (d) $4.8\times10^{-9}N$

38. The electric field $\vec{E} = E_0\sin(\omega t - kz)\hat{x} + 2E_0\sin(\omega t - kz + \pi/2)\hat{y}$ represents:

(a) a linearly polarized wave (b) a right hand circularly polarized wave

(c) a left hand circularly polarized wave (d) an elliptically polarized wave

39. The electric field component of a plane electromagnetic wave travelling in vacuum is given b $\vec{E}(z,t) = E_0\cos(kz-\omega t)\hat{i}$. The Poynting vector for the wave is **[GATE 2016]**

(a) $(c\varepsilon_0/2)E_0^2\cos^2(kz-\omega t)\hat{j}$ (b) $(c\varepsilon_0/2)E_0^2\cos^2(kz-\omega t)\hat{k}$

(c) $c\varepsilon_0E_0^2\cos^2(kz-\omega t)\hat{j}$ (d) $c\varepsilon_0E_0^2\cos^2(kz-\omega t)\hat{k}$

40. Let a right circularly polarized light be incident normally on an ordinary mirro. The reflected light is:

(a) Elliptically polarized (b) Right circularly polarized

(c) Left circularly polarized (d) Linearly polarized

41. At time $t=0$, a charge distribution $\rho(\vec{r},0)$ exists within an ideal homogeneous conductor of permitivity ε and conductivity σ. At a later time $\rho(\vec{r},t)$ is given by **[GATE 2008]**

(a) $\rho(\vec{r},t) = \rho(\vec{r},0)\exp\left(-\dfrac{\sigma t}{\varepsilon}\right)$ (b) $\rho(\vec{r},t) = \dfrac{\rho(\vec{r},0)}{1+(\sigma t/\varepsilon)^2}$

(c) $\rho(\vec{r},t) = \rho(\vec{r},0)\exp\left[-\left(\dfrac{\sigma t}{\varepsilon}\right)^2\right]$ (d) $\rho(\vec{r},t) = \rho(\vec{r},0)\exp\dfrac{\varepsilon}{\sigma t}\sin\left(\dfrac{\sigma t}{\varepsilon}\right)$

42. The frequency dependent dielectric constant of a material is given by

$$\varepsilon(\omega) = 1 + \frac{A}{\omega_0^2 - \omega^2 - i\omega\gamma}$$

where A is a positive constant, ω_0 the resonant frequency and γ the damping coefficient. For an electro-magnetic wave of angular frequency $\omega << \omega_0$, which of the following is true? (Assume that $\frac{\gamma}{\omega_0} << 1$).

(a) there is negligible absorption of the wave
(b) the wave propagation is highly dispersive
(c) there is strong absorption of the electromagnetic wave
(d) the group velocity and hte phase velocity will have opposite sign.

43. Maxwell's equations can be written in terms of two coupled equations satisfied by the vector potential $\vec{A}$ and scalar potential ϕ. The Lorentz gauge which decouples these equations is given by

(a) $\vec{\nabla}.\vec{A} = 0$ (b) $\nabla^2\phi = \frac{1}{c^2}\frac{\partial^2\vec{A}}{\partial t^2}$ (c) $\vec{\nabla}.\vec{A} = -\frac{1}{c^2}\frac{\partial\phi}{\partial t}$ (d) $\vec{\nabla}.\vec{A} = \frac{1}{c}\frac{\partial\phi}{\partial t}$

44. Of A and V are vector and scalar potential $V(r,t) = 0$, $A(r,t) = \frac{-q}{4\pi\in_0}\frac{t\,\hat{r}}{r^3}$. Scalar function $\lambda = \frac{-q}{4\pi\in_0}\frac{t}{r^2}$

Due to gauge transformation transformed potential is

(a) $V'(r,t) = 0 \quad A(r,t) = \frac{q}{4\pi\in_0}t\frac{1}{r^2}$ (b) $V'(r,t) = \frac{q}{4\pi\in_0 r^2} \quad A(r,t) = \frac{q}{4\pi\in_0}t\frac{1}{r^2}$

(c) $V'(r,t) = \frac{-q}{4\pi\in_0}\frac{1}{r^2} \quad A'(r,t) = \frac{-qt}{4\pi\in_0}\frac{1}{r^2}$ (d) $V'(r,t) = \frac{q}{4\pi\in_0}\frac{1}{r^2} \quad A'(r,t) = \frac{qt}{4\pi\in_0 r^3}$

45. Which of the following transformations $(V,\vec{A}) \rightarrow (V',\vec{A}')$ of the electrostatic potential V and the vector potential $\vec{A}$ is a gauge transformation?

[NET June 2015]

(a) $(V' = V + ax, \vec{A}' = \vec{A} + at\,\hat{k})$ (b) $(V' = V + ax, \vec{A}' = \vec{A} - at\,\hat{k})$
(c) $(V' = V + ax, \vec{A}' = \vec{A} + at\,\hat{i})$ (d) $(V' = V + ax, \vec{A}' = \vec{A} - at\,\hat{i})$

46. The condition for a vector potential $\vec{\Lambda}$ to satisfy the wave equation is:

(a) $\vec{\nabla}.\vec{\Lambda} = 0$ (b) $\vec{\nabla}.\vec{\Lambda} + \mu_0 \in_0 \frac{\partial\phi}{\partial t} = 0$

(c) $\frac{\partial\vec{\Lambda}}{\partial t} + \mu_0 \in_0 \vec{\nabla}\phi = 0$ (d) $\vec{A} + \vec{\nabla}\phi = 0$

47. An electro-magnetic field is defined by a scalar potential $\phi(\vec{r},t) = 0$ and vector potential $\vec{A}(\vec{r},t) = \frac{1}{4\pi\varepsilon_0}\frac{qt}{r^2}\hat{r}$.

The corresponding electric field is :

(a) $\vec{E} = 0$ (b) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (c) $\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (d) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{\theta}$

48. For a vector potential $\vec{A}$, the divergence of $\vec{A}$ is $\vec{\nabla}\cdot\vec{A} = -\frac{\mu_0}{4\pi}\frac{Q}{r^2}$, where Q is a constant of ap

dimension. The corresponding scalar potential $\phi(\vec{r},t)$ that makes $\vec{A}$ and ϕ Lorentz gauge invar

(GATE 201

(a) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{Qt}{r}$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{Qt}{r^2}$

49. The scalar and vector potentials $\varphi(\vec{x},t)$ and $\vec{A}(\vec{x},t)$ are determined up to a gauge transf

$\varphi \to \varphi' = \varphi - \frac{\partial\xi}{\partial t}$ and $\vec{A} \to \vec{A}' = \vec{A} + \vec{\nabla}\xi$ where ξ is an arbitrary continuous and differentiable functi

and t. If we further impose the Lorentz gauge condition $\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial\varphi}{\partial t} = 0$ then a possible choice for the

function $\xi(\vec{x},t)$ is (where $\omega, \vec{k}$ are non-zero constants with $\omega = c|\vec{k}|$) [NET Dec. 2

(a) $\cos\omega t \cosh\vec{k}\cdot\vec{x}$ (b) $\sinh\omega t \cos\vec{k}\cdot\vec{x}$

(c) $\cosh\omega t \cos\vec{k}\cdot\vec{x}$ (d) $\cosh\omega t \cosh\vec{k}\cdot\vec{x}$

50. If the electric and magnetic fields are unchanged when the vector potential $\vec{A}$ changes (in suitab according to $\vec{A} \to \vec{A} + \hat{r}$, where $\vec{r} = r(t)\hat{r}$, then the scalar potential ϕ must simultaneously chang

[NET June 2

(a) $\phi - r$ (b) $\phi + r$ (c) $\phi - \partial r/\partial t$ (d) $\phi + \partial r/\partial t$

51. Consider an infinite conducting sheet in the xy-plane with a time dependent current density $Kt\hat{i}$, wh is a constant. The vector potential at (x, y, z) is given by [NET Dec. 2

$$\vec{A} = \frac{\mu_0 K}{4c}(ct-z)^2\,\hat{i}$$

The magnetic field $\vec{B}$ is:

(a) $\frac{\mu_0 Kt}{2}\hat{j}$ (b) $-\frac{\mu_0 Kz}{2c}\hat{j}$ (c) $-\frac{\mu_0 K}{2c}(ct-z)\hat{j}$ (d) $-\frac{\mu_0 K}{2c}(ct-z)\hat{i}$

52. A constant electric current I in an infinitely long straight wire is suddenly switched on at t = 0. The v

potential at a perpendicular distance r from the wire is given by $\vec{A} = \frac{\hat{k}\mu_0 I}{2\pi}\ln\left(\frac{1}{r}\left(ct+\sqrt{c^2t^2-r^2}\right)\right)$. The e

tric field at a distance $r(<ct)$ is: [NET Dec. 20

(a) 0 (b) $\frac{\mu_0 I}{2\pi}\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$ (c) $\frac{c\mu_0 I}{2\pi\sqrt{c^2t^2-r^2}}\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$ (d) $-\frac{c\mu_0}{2\pi\sqrt{c^2t^2-}}$

48. For a vector potential $\vec{A}$, the divergence of $\vec{A}$ is $\vec{\nabla}.\vec{A} = -\frac{\mu_0}{4\pi}\frac{Q}{r^2}$, where Q is a constant of appropri dimension. The corresponding scalar potential $\varphi(\vec{r},t)$ that makes $\vec{A}$ and φ Lorentz gauge invariant is :

[GATE 2005]

(a) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{Qt}{r}$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{Qt}{r^2}$

49. The scalar and vector potentials $\varphi(\vec{x},t)$ and $\vec{A}(\vec{x},t)$ are determined up to a gauge transformati $\varphi \to \varphi' = \varphi - \frac{\partial\xi}{\partial t}$ and $\vec{A} \to \vec{A}' = \vec{A} + \vec{\nabla}\xi$ where ξ is an arbitrary continuous and differentiable function of and t. If we further impose the Lorentz gauge condition $\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial\varphi}{\partial t} = 0$ then a possible choice for the gau function $\xi(\vec{x},t)$ is (where $\omega, \vec{k}$ are non-zero constants with $\omega = c|\vec{k}|$) **[NET Dec. 2014]**

(a) $\cos\omega t \cosh\vec{k}\cdot\vec{x}$ (b) $\sinh\omega t \cos\vec{k}\cdot\vec{x}$

(c) $\cosh\omega t \cos\vec{k}\cdot\vec{x}$ (d) $\cosh\omega t \cosh\vec{k}\cdot\vec{x}$

50. If the electric and magnetic fields are unchanged when the vector potential $\vec{A}$ changes (in suitable uni according to $\vec{A} \to \vec{A} + \hat{r}$, where $\vec{r} = r(t)\hat{r}$, then the scalar potential Φ must simultaneously change to

[NET June 2013]

(a) $\Phi - r$ (b) $\Phi + r$ (c) $\Phi - \partial r/\partial t$ (d) $\Phi + \partial r/\partial t$

51. Consider an infinite conducting sheet in the xy-plane with a time dependent current density $Kt\hat{i}$, where K is a constant. The vector potential at (x, y, z) is given by **[NET Dec/ 2012]**

$$\vec{A} = \frac{\mu_0 K}{4c}(ct - z)^2\,\hat{i}$$

The magnetic field $\vec{B}$ is:

(a) $\frac{\mu_0 Kt}{2}\hat{j}$ (b) $-\frac{\mu_0 Kz}{2c}\hat{j}$ (c) $-\frac{\mu_0 K}{2c}(ct - z)\hat{i}$ (d) $-\frac{\mu_0 K}{2c}(ct - z)\hat{j}$

52. A constant electric current I in an infinitely long straight wire is suddenly switched on at $t = 0$. The vecto potential at a perpendicular distance r from the wire is given by $\vec{A} = \frac{\hat{k}\mu_0 I}{2\pi}\ell n\left[\frac{1}{r}\left(ct + \sqrt{c^2t^2 - r^2}\right)\right]$. The electric field at a distance $r(< ct)$ is: **[NET Dec. 2011]**

(a) 0 (b) $\frac{\mu_0 I}{2\pi t}\frac{1}{\sqrt{2}}(\hat{i} - \hat{j})$ (c) $\frac{c\mu_0 I}{2\pi\sqrt{c^2t^2 - r^2}}\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$ [✓ (d)] $\frac{c\mu_0 I}{2\pi\sqrt{c^2t^2 - r^2}}\hat{k}$

53. Consider a solenoid of radius R with n turns per unit length, in which a time dependent current $I = I_0 \sin \omega t$ (where $\omega R/c \ll 1$) flows. The magnitude of the electric field at a perpendicular distance $r < R$ from the axis of symmetry of the solenoid, is: **[NET Dec. 2011]**

(a) 0

(b) $\frac{1}{2r}\omega\mu_0 n I_0 R^2 \cos\omega t$

(c) $\frac{1}{2}\omega\mu_0 n I_0 r \sin\omega t$

(d) $\frac{1}{2}\omega\mu_0 n I_0 r \cos\omega t$

54. A time-dependent current $\vec{I}(t) = Kt\hat{z}$ (where K is a constant) is switched on at $t = 0$ in an infinite current-carrying wire. The magnetic vector potential at a perpendicular distance 'a' from the wire is given (for time $t > a/c$) by **[NET June 2014]**

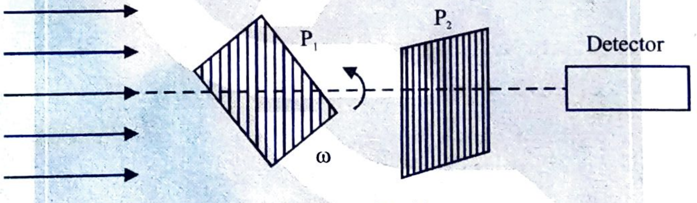
(a) $\hat{z}\frac{\mu_0 K}{4\pi c}\int_{-\sqrt{c^2t^2-a^2}}^{\sqrt{c^2t^2-a^2}} dz \frac{ct-\sqrt{a^2+z^2}}{\left(a^2+z^2\right)^{1/2}}$

(b) $\hat{z}\frac{\mu_0 K}{4\pi}\int_{-ct}^{ct} dz \frac{ct-\sqrt{a^2+z^2}}{\left(a^2+z^2\right)^{1/2}}$

(c) $\hat{z}\frac{\mu_0 K}{4\pi c}\int_{-ct}^{ct} dz \frac{ct-\sqrt{a^2+z^2}}{\left(a^2+z^2\right)^{1/2}}$

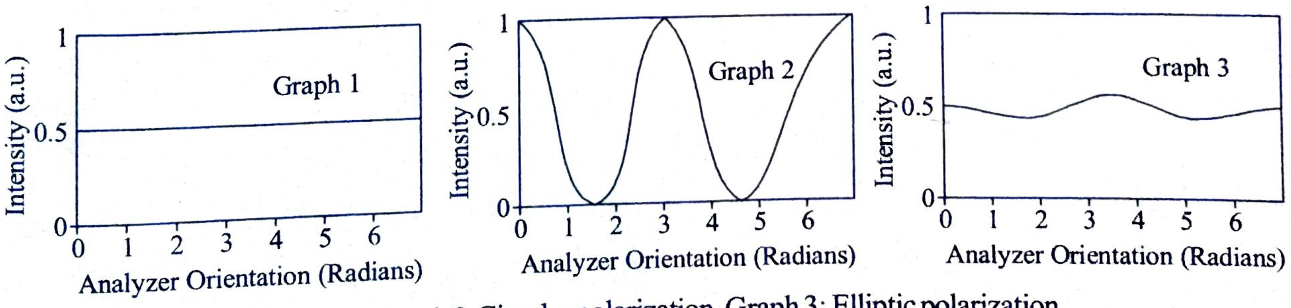
(d) $\hat{z}\frac{\mu_0 K}{4\pi}\int_{-\sqrt{c^2t^2-a^2}}^{\sqrt{c^2t^2-a^2}} dz \frac{t}{\left(a^2+z^2\right)^{1/2}}$

55. A linear beam of unpolarised light passes through tow plane polarisers, the planes of which are perpendicular to the direction of propagation of the beam. The first polariser rotates around this direction with an angular velocity of 20π radians per second. If the initial intensity of the light is I_0, then the intensity when it leaves the second polariser



(a) is periodic with frequency of 20 Hz and maximum of $I_0/4$
(b) is periodic with frequency of 20 Hz and maximum of $I_0/2$
(c) is periodic with frequency of 10 Hz and maximum of $I_0/4$
(d) is periodic with frequency of 10 Hz and maximum of $I_0/2$

56. Intensity of three different light beams after passing through an analyzer is found to vary as shown in the following graphs. Identify the option giving the correct states of polarization of the incident beams from the graphs.



(a) Graph 1: Linear polarization, Graph 2: Circular polarization, Graph 3: Elliptic polarization.
(b) Graph 1: Circular polarization, Graph 2: Linear polarization, Graph 3: Elliptic polarization.
(c) Graph 1: Unpolarized, Graph 2: Circular polarization, Graph 3: Linear polarization.
(d) Graph 1: Unpolarized, Graph 2: Elliptic polarization, Graph 3: Circular polarization.

57. **Group-I** contains x- and y-components of the electric field and **Group-II** contains the type of polarization light.

Group-I	**Group-II**
P. $E_x = \frac{E_0}{\sqrt{2}}\cos(\omega t + kz)$ $E_y = E_0 \sin(\omega t + kz)$	1. Linearly polarized
Q. $E_x = E_0 \sin(\omega t + kz)$ $E_y = E_0 \cos(\omega t + kz)$	2. Circularly polarized
R. $E_x = E_1 \sin(\omega t + kz)$ $E_y = E_2 \sin(\omega t + kz)$	3. Unpolarized
S. $E_x = E_0 \sin(\omega t + kz)$ $E_y = E_0 \sin\left(\omega t + kz + \frac{\pi}{4}\right)$	4. Elliptically polarized

The correct set of matches is

(a) $P \to 4;\ Q \to 2;\ R \to 4;\ S \to 1$
(b) $P \to 1;\ Q \to 3;\ R \to 1;\ S \to 4$
(c) $P \to 4;\ Q \to 2;\ R \to 1;\ S \to 4$
(d) $P \to 3;\ Q \to 1;\ R \to 3;\ S \to 2$

58. The skin depth of the electromagnetic waves in a poor conductor is:

(a) $\omega\sqrt{\frac{\varepsilon\mu}{2}}\left[\sqrt{1+\left(\frac{\sigma}{\varepsilon\omega}\right)^2}-1\right]^{1/2}$
(b) $\omega\sqrt{\frac{\varepsilon\mu}{2}}$
(c) $\frac{2}{\sigma}\sqrt{\frac{\varepsilon}{\mu}}$
(d) $\frac{\lambda}{2\pi}$

59. The electric field of an electromagnetic wave is $\vec{E}(z,t) = E_0\cos(kz+\omega t)\hat{i} + 2E_0\sin(kz+\omega t)\hat{j}$, where ω and k are positive constants. This represents **[NET Dec. 2016]**

(a) a linearly polarised wave travelling in the positive z-direction
(b) a circularly polarised wave travelling in the negative z-direction
(c) an elliptically polarised wave travelling in the negative z-direction
(d) an unpolarised wave travelling in the positive z-direction

60. Suppose that free charges are present in a material of dielectric (ε_r) constant $\varepsilon = 10$ and resistivity $\rho = 10^{11}\ \Omega$-m. Using Ohm's law and the equation of continuity for charge, the time required for the charge density inside the material to decay by $1/e$ is closest to **[NET Dec. 2016]**

(a) 10^{-6} s
(b) 10^{6} s
(c) 10^{12} s
(d) 10 s

61. A beam of plane microwaves of wavelength 12 cm strikes the surface of a dielectric at 45°. If the refractive index of the dielectric is 4/3, what will be the wavelength, in units of mm, of the microwaves inside the dielectric? **[TIFR 2017]**

62. An electromagnetic wave in free space is described by $\vec{E}(x,y,z,t) = \hat{z}\,E_0\cos\frac{1}{2}(kx - \sqrt{3}ky - 2\omega t)$. The Poynting vector associated with this wave is along the direction **[TIFR 2017]**

(a) $\hat{x} + \sqrt{3}\,\hat{y}$
(b) $\sqrt{3}\,\hat{x} + \hat{y}$
(c) $-\sqrt{3}\,\hat{x} + \hat{y}$
(d) $\hat{x} - \sqrt{3}\,\hat{y}$

63. An infinite solenoid carries a time varying current $I(t) = At^2$, with $A \neq 0$. the axis of the solenoid is along the $\hat{z}$ direction. $\hat{r}$ and $\hat{\theta}$ are the usual radial and polar directions in cylindrical polar coordinates. $\vec{B} = B_r\hat{r} + B_\theta\hat{\theta} + B_z\hat{z}$ is the magnetic field at a point outside the solenoid. Which one of the following statements is true? **[GATE 2017]**

(a) $B_r = 0, B_\theta = 0, B_z = 0$ (b) $B_r \neq 0, B_\theta \neq 0, B_z = 0$

(c) $B_r \neq 0, B_\theta \neq 0, B_z \neq 0$ (d) $B_r = 0, B_\theta = 0, B_z \neq 0$

64. Consider a metal with free electron density of $6 \times 10^{22}\ \text{cm}^{-3}$. The lowest frequency electromagnetic radiation to which this metal is transparent is 1.38×10^{16} Hz. If this metal had a free electron density of $1.8 \times 10^{23}\ \text{cm}^{-3}$ instead, the lowest frequency electromagnetic radiation to which it would be transparent is ________ $\times 10^{16}$ Hz. (up to two decimal places). **[GATE 2017]**

65. A plane electromagnetic wave propagating in air with $\vec{E} = (8\hat{i} + 6\hat{j} + 5\hat{k})e^{i(\omega t + 3x - 4y)}$ is incident on a perfectly conducting slab positioned at $x = 0$. $\vec{E}$ field of the reflected wave is **[JEST 2017]**

(a) $(-8\hat{i} - 6\hat{j} - 5\hat{k})e^{i(\omega t + 3x + 4y)}$ (b) $(-8\hat{i} + 6\hat{j} - 5\hat{k})e^{i(\omega t + 3x + 4y)}$

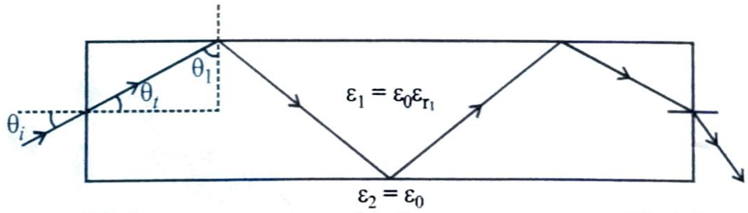
(c) $(-8\hat{i} + 6\hat{j} - 5\hat{k})e^{i(\omega t - 3x - 4y)}$ (d) $(-8\hat{i} - 6\hat{j} - 5\hat{k})e^{i(\omega t - 3x - 4y)}$

66. The wave number of an electromagnetic wave incident on a metal surface is $(20\pi + 750i)m^{-1}$ inside the metal, where $i = \sqrt{-1}$. The skin depth of the wave in the metal is ____________
(Specify your answer in mm to two digits after the decimal point)

67. An electromagnetic wave (of wavelength λ_0 in free space) travels through an absorbing medium with dielectric permittivity given by $\varepsilon = \varepsilon_R + i\varepsilon_I$, where $\frac{\varepsilon_I}{\varepsilon_R} = \sqrt{3}$. If the skin depth is $\frac{\lambda_0}{4\pi}$, the ratio of the amplitude of electric field E to that of the magnetic field B, in the medium (in ohms) is **[NET June 2017]**

(a) 120π (b) 377 (c) $30\sqrt{2}\,\pi$ ~~(d)~~ 30π

68. A dielectric rod of a transparent material can be used to guide light under the condition of total internal reflection. What is the minimum dielectric constant of the guiding medium so that a wave incident on one end at any angle will be confined within the rod until it emerges from the other end ?



θ_1
θ_t
θ_i
$\varepsilon_1 = \varepsilon_0\varepsilon_{r_1}$
$\varepsilon_2 = \varepsilon_0$

(a) $\sqrt{2}$ (b) 1 (c) 2 (d) 1.5 (e) 1.75

69. The vector potential $\vec{A} = ke^{-at}r\hat{r}$, (where a and k are constants) corresponding to an electromagnetic field is changed to $\vec{A}' = -ke^{-at}r\hat{r}$. This will be a gauge transformation if the corresponding change $\phi' - \phi$ in the scalar potential is **[NET June 2017]**

(a) akr^2e^{-at} (b) $2akr^2e^{-at}$ (c) $-akr^2e^{-at}$ (d) $-2akr^2e^{-at}$

70. An electromagnetic wave is travelling in free space (of permittivity ε_0) with electric field $\vec{E}=\hat{k}E_0\cos k(x-ct)$. The average power (per unit area) crossing planes parallel to $4x+3y=0$ will be **[NET Dec. 2017]**

(a) $\frac{4}{5}\varepsilon_0 c E_0^2$ (b) $\varepsilon_0 c E_0^2$ (c) $\frac{1}{2}\varepsilon_0 c E_0^2$ (d) $\frac{16}{25}\varepsilon_0 c E_0^2$

71. A plane electromagnetic wave from within a dielectric medium (with $\varepsilon=4\varepsilon_0$ and $\mu=\mu_0$) is incident on its boundary with air, at $z=0$. The magnetic field in the medium is $\vec{H}=\hat{j}H_0\cos\left(\omega t-kx-k\sqrt{3}z\right)$, where ω and k are positive constants. The angles of reflection and refraction are, respectively, **[NET Dec. 2017]**

(a) 45° and 60° (b) 30° and 90° (c) 30° and 60° (d) 60° and 90°

72. A plane electromagnetic wave, which has an electric field **[TIFR 2018]**

$$\vec{E}(\vec{x},t)=\left(P\hat{i}+Q\hat{j}\right)\exp i\omega\left(t-\frac{z}{c}\right)$$

is passing through vacuum. Here, P, Q and ω are all constants, while c is the speed of light in vacuum. What is the average energy flux per unit time (in SI units) crossing a unit area placed normal to the direction of propagation of this wave, in terms of the above constants?

73. The electric field of a plane wave in a conducting medium is given by **[NET June 2018]**

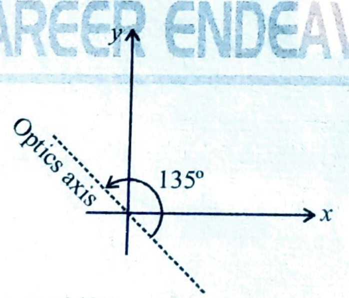
$$\vec{E}(z,t)=\hat{i}\,E_0\,e^{-z/3a}\cos\left(\frac{z}{\sqrt{3}a}-\omega t\right),$$

where ω is the angular frequency and $a>0$ is a constant. The phase difference between the magnetic field $\vec{B}$ and the electric field $\vec{E}$ is

(a) 30° and $\vec{E}$ lags behind $\vec{B}$ (b) 30° and $\vec{B}$ lags behind $\vec{E}$
(c) 60° and $\vec{E}$ lags behind $\vec{B}$ (d) 60° and $\vec{B}$ lags behind $\vec{E}$

74. A light beam of intensity I_0 is falling normally on a surface. The surface absorbs 20% of the intensity and the rest is reflected. The radiation pressure on the surface is given by $X\,I_0/c$, where X is ________ (up to one decimal place). Here c is the speed of light. **[GATE 2018]**

75. A quarter wave plate introduces a path difference of $\lambda/4$ between the two components of polarization parallel and perpendicular to the optic axis. An electromagnetic wave with $\vec{E}=(\hat{x}+\hat{y})E_0\,e^{i(kz-\omega t)}$ is incident normally on a quarter wave plate which has its optic axis making an angle 135° with the x-axis as shown.



The emergent electromagnetic wave would be **[GATE 2018]**

(a) elliptically polarized
(b) circularly polarized
(c) linearly polarized with polarization as that of incident wave
(d) linearly polarized but with polarization at 90° to that of the incident wave

76. A long straight wire, having radius a and resistance per unit length r, carries a current I. The magnitude and direction of the Poynting vector on the surface of the wire is

(a) $\frac{I^2 r}{2\pi a}$, perpendicular to axis of the wire and pointing inwards. **[GATE 2018]**

(b) $\frac{I^2 r}{2\pi a}$, perpendicular to axis of the wire and pointing outwards.

(c) $\frac{I^2 r}{\pi a}$, perpendicular to axis of the wire and pointing inwards.

(d) $\frac{I^2 r}{\pi a}$, perpendicular to axis of the wire and pointing outwards.

77. An electromagnetic plane wave is propagating with an intensity $I = 1.0 \times 10^5\ \text{Wm}^{-2}$ in a medium with $\varepsilon = 3\varepsilon_0$ and $\mu = \mu_0$. The amplitude of the electric field inside the medium is ________ $\times 10^3\ \text{Vm}^{-1}$ (up to one decimal place). **[GATE 2018]**

$$\left[\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\text{m}^{-2},\ \mu_0 = 4\pi \times 10^{-7}\ \text{NA}^{-2},\ c = 3 \times 10^8\ \text{ms}^{-1}\right]$$

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

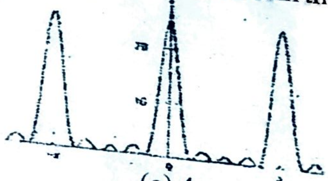
Assignment-8 : Electromagntic Theory

1. A plane wave $(\hat{x}+i\hat{y})E_0\exp[i(kz-\omega t)]$ after passing through an optical element emerges as $(\hat{x}-i\hat{y})E_0\exp[i(kz-\omega t)]$, where k and ω are the wavevector and the angular frequency, respectively. The optical element is **[GATE 2015]**
(a) quarter wave plate (b) half wave plate
(c) polarizer (d) Faraday rotator

2. For a transparent material the ratio of reflected intensity to the incident intensity depends on
(a) its absorption coefficient
(b) its refractive index only
(c) its absorption coefficient and transmission coefficients
(d) its high transmission coefficient

3. The electric fields of two light sources with nearby frequencies ω_1 and ω_2, and wave vectors k_1 and k_2 are expressed as $\vec{E}_1 = E_{10}\hat{i}e^{-i(k_1z-\omega_1t)}$ and $\vec{E}_2 = E_{20}\hat{i}e^{-i(k_2z-\omega_2t)}$, respectively. The interference pattern on the screen is photographed at $t=t_0$; denote $(k_1-k_2)z-(\omega_1-\omega_2)t_0$ by θ. For this pattern
(a) a bright fringe will be obtained for $\cos\theta=-1$
(b) a bright fringe intensity is given by $(E_{10})^2+(E_{20})^2$
(c) a dark fringe will be obtained for $\cos\theta=1$
(d) a dark fringe intensity is given by $(E_{10}-E_{20})^2$

4. The diffraction pattern from a grating with N slits is shown in the figure. The value of N is



(a) 3 (b) 5 (c) 4 (d) 2

An electromagnetic wave is normally incident upon a perfectly conducting surface. In the reflected wave,
(a) $\vec{H}$ is shifted 180° in phase. (b) $\vec{E}$ is shifted 180° in phase
(c) $\vec{H}$ is shifted 90° in phase (d) $\vec{E}$ is shifted 90° in phase.

In which region of the electromagnetic spectrum do metals have the highest reflectivity?
(a) Infrared (b) Visible
(c) Ultraviolet (d) In the entire region of the spectrum

The instantaneous electric and magnetic fields created at a distance 'r' by a point source at the origin are given by

$$\vec{E} = \frac{A\cos\omega t}{2\pi\varepsilon_0 r}\hat{\theta} \qquad \hat{H} = \frac{B\cos\omega t}{\mu_0 r}\hat{\varphi}$$

[TIFR 2014]

where ω, A, B are constants, and the unit vectors $\left(\hat{r}, \hat{\theta}, \hat{\varphi}\right)$ form an orthonormal set. The time-averaged power radiated by the source is

(a) $\frac{\omega\varepsilon_0}{\mu_0}AB$ (b) $\frac{c^3}{2\pi}AB$ (c) c^2AB (d) $\frac{2\pi\omega}{c}AB$

8. The magnetic vector potential $\vec{A}\left(\vec{r}\right)$ corresponding to a uniform magnetic field $\vec{B}$ is taken in the form

$$\vec{A} = \frac{1}{2}\vec{B}\times\vec{r}$$

where '$\vec{r}$' is the position vector. If the electric field has the time dependent form $\vec{E} = \vec{E}_0\left(\vec{r}\right)e^{i\omega t}$, where '$\omega$' is a constant, the gauge choice corresponding to this potential is a **[TIFR 2013]**

(a) Lorenz gauge (b) Coulomb gauge (c) Non-linear gauge (d) Time-varying gauge.

Common Data for Q.9 and Q.10 **[GATE 2007]**

The Fresnel relations between the amplitudes of incident and reflected electromagnetic waves at an interface between air and a dielectric of refractive index μ, are

$$E_{\parallel}^{reflected} = \frac{\cos r - \mu\cos i}{\cos r + \mu\cos i}E_{\parallel}^{incident} \text{ and } E_{\perp}^{reflected} = \frac{\cos i - \mu\cos r}{\cos r + \mu\cos i}E_{\perp}^{incident}$$

The subscripts || and $\perp$ refer to polarization, parallel to the plane of incidence respectively. Here, i and *r* are the angles of incidence and refraction respectively.

9. The condition for the reflected ray to be completely polarized is

(a) $\mu\cos i = \cos r$ (b) $\cos i = \mu\cos r$ (c) $\mu\cos i = -\cos r$ (d) $\cos i = -\mu\cos r$

10. For normal incident at an air-glass interface with μ = 1.5 the fraction of energy reflected is given by

(a) 0.40 (b) 0.20 (c) 0.16 (d) 0.04

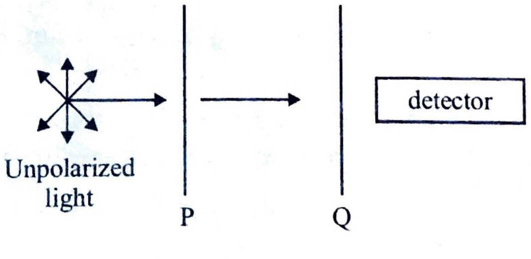
11. A monochromatic plane wave at oblique incidence undergoes reflection at a dielectric interface. If $\hat{k}_i$, $\hat{k}_r$ and $\hat{n}$ are the unit vectors in the directions of incident wave, reflected wave and the normal to the surface respectively, which one of the following expression is correct? **[GATE 2013]**

(a) $(\hat{k}_i - \hat{k}_r)\times\hat{n} \neq 0$ (b) $(\hat{k}_i - \hat{k}_r)\cdot\hat{n} = 0$ (c) $(\hat{k}_i \times\hat{n})\cdot\hat{k}_r = 0$ (d) $(\hat{k}_i \times\hat{n})\cdot\hat{k}_r \neq 0$

12. A circularly polarized monochromatic plane wave is incident on a dielectric interface at Brewster angle. Which one of the following statements is **CORRECT**? **[GATE 2013]**

(a) The reflected light is plane polarized in the plane of incidence and the transmitted light is circularly polarized.
(b) The reflected light is plane polarized perpendicular to the plane of incidence and the transmitted light is plane polarized in the plane of incidence.
(c) The reflected light is plane polarized perpendicular to the plane of incidence and the transmitted light is elliptically polarized.
(d) There will be no reflected light and the transmitted light is circularly polarized.

13. In the optical arrangement as shown below, the axes of two polarizing sheets P and Q are oriented such that no light is detected. Now when a third polarizing sheet (R) is placed in between P and Q, then light is detected. Which of the following statement(s) is (are) true?



(a) polarization axes of P and Q are perpendicular to each other

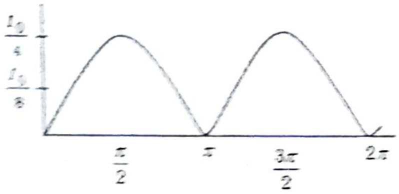
(b) polarization axis of R is not parallel to P

(c) polarization axis of R is not parallel to Q

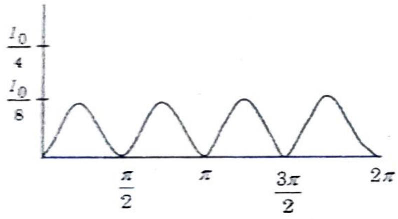
(d) polarization axes of P and Q are parallel to each other.

14. Three polarizers P, Q and R are placed parallel to each other with their planes perpendicular to the z-a Q is placed between P and R. Initially the polarizing directions of P and Q are parallel, but that of R perpendicular to them. In this arrangement when unpolarized light of intensity I_0 is incident on P, the inten coming out of R is zero. The polarizer Q is now rotated about the z-axis. As a function of angle of rotatio the intensity of light coming out of R is best represented by

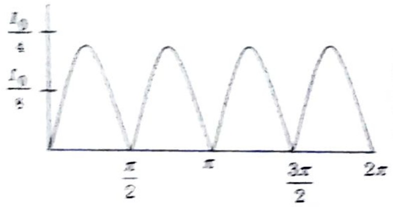
(a)



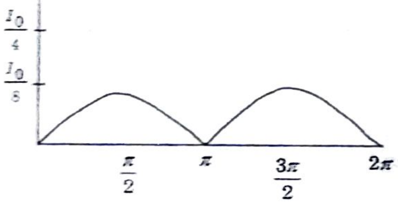
(b)



(c)



(d)



15. Interference fringes are seen at an observation plane $z=0$, by the superposition of two plane waves $A_1 \exp[i(\vec{k}_1\cdot\vec{r}-\omega t)]$ and $A_2 \exp[i(\vec{k}_2\cdot\vec{r}-\omega t)]$, where A_1 and A_2 are real amplitudes. The condition for interference maximum is

[GATE 2013]

(a) $(\vec{k}_1-\vec{k}_2)\cdot\vec{r}=(2m+1)\pi$

(b) $(\vec{k}_1-\vec{k}_2)\cdot\vec{r}=2m\pi$

(c) $(\vec{k}_1+\vec{k}_2)\cdot\vec{r}=(2m+1)\pi$

(d) $(\vec{k}_1+\vec{k}_2)\cdot\vec{r}=2m\pi$

16. A plane electromagnetic wave travelling in vaccum is incident normally on a non magnetic, non-absorbing medium of refractive index n. The incident (E_i), reflected (E_r) and transmitted (E_t) electric fields are given as.

[GATE 2005]

$$E_i = E\exp\left[i(kz-\omega t)\right],\ E_r = E_{0r}\exp\left[i(k_r z-\omega t)\right],\ E_t = E_{0t}\exp\left[i(k_t z-\omega t)\right]$$

If $E = 2$ V/m and $n = 1.5$ then the application of appropriate boundary conditions leads to :

(a) $E_{0r} = -\frac{3}{5}\,\text{V/m},\ E_{0t} = \frac{7}{5}\,\text{V/m}$

(b) $E_{0r} = -\frac{1}{5}\,\text{V/m},\ E_{0t} = \frac{8}{5}\,\text{V/m}$

(c) $E_{0r} = -\frac{2}{5}\,\text{V/m},\ E_{0t} = \frac{8}{5}\,\text{V/m}$

(d) $E_{0r} = \frac{4}{5}\,\text{V/m},\ E_{0t} = \frac{6}{5}\,\text{V/m}$

17. A left circularly polarized light beam of wavelength 600 nm is incident on a crystal of thickness d and propagated perpendicular to its optic axis. The ordinary and extraordinary refractive indices of the crystal are $n_0 = 1.54$ and $n_e = 1.55$ respectively. The emergent light will be right circularly polarized if d is :

(a) 120 μm (b) 60 μm (c) 30μm (d) 15μm **[GATE 2002]**

18. A plane electromagnetic wave incident normally on the surface of a material is partially reflected. Measurements on the standing wave in the region in front of the interface show that the ratio of the electric field amplitude at the maxima and the minima is 5. The ratio of the reflected intensity to the incident intensity is
(a) 4/9 (b) 2/3 (c) 2/5 (d) 1/5 **[NET Dec. 2014]**

19. A beam of light of frequency ω is reflected from a dielectric-metal interface at normal incience. the refractive index of the dielectric medium is n and that of the metal is $n_2 = n(1+i\rho)$. If the beam is polarised parallel to the interface, then the phase change experienced by the light upon reflection is

(a) $\tan\left(\frac{2}{\rho}\right)$ (b) $\tan^{-1}\left(\frac{1}{\rho}\right)$ (c) $\tan^{-1}\left(\frac{2}{\rho}\right)$ (d) $\tan^{-1}(2\rho)$

20. Let (V, A) and (V', A') denote two sets of scalar and vector potentials, and ψ a scalar function. Which of the following transformations leave the electric and magnetic fields (and hence Maxwell's equations) unchanged? **[NET Dec. 2013]**

(a) $A' = A + \nabla\psi$ and $V = V - \frac{\partial\psi}{\partial t}$ (b) $A' = A - \nabla\psi$ and $V' = V + 2\frac{\partial\psi}{\partial t}$

(c) $A' = A + \nabla\psi$ and $V' = V + \frac{\partial\psi}{\partial t}$ (d) $A' = A - 2\nabla\psi$ and $V' = V - \frac{\partial\psi}{\partial t}$

21. A current I is created by a narrow beam of protons moving in vacuum with constant velocity $\bar{u}$. The direction and magnitude, respectively, of the Poynting vector $\bar{S}$ outside the beam at a radial distance r (much larger than the width of the beam) from the axis, are **[NET June 2013]**

(a) $\bar{S} \perp \bar{u}$ and $|\bar{S}| = \frac{I^2}{4\pi^2 \epsilon_0 |\bar{u}| r^2}$ (b) $\bar{S} \| (-\bar{u})$ and $|\bar{S}| = \frac{I^2}{4\pi^2 \epsilon_0 |\bar{u}| r^4}$

(c) $\bar{S} \| \bar{u}$ and $|\bar{S}| = \frac{I^2}{4\pi^2 \epsilon_0 |\bar{u}| r^2}$ (d) $\bar{S} \| \bar{u}$ and $|\bar{S}| = \frac{I^2}{4\pi^2 \epsilon_0 |\bar{u}| r^4}$

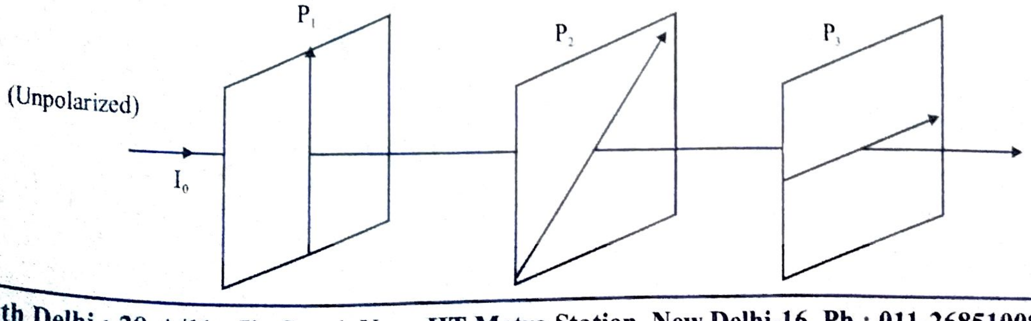
22. An electromagnetic wave is incident on a water-air interface. The phase of the perpendicular component of the electric field, $E_\perp$, of the reflected wave into the water is found to remain the same for ail angles of incidence. The phase of the magnetic field H. **[NET June 2012]**

(a) does not change (b) changes by $3\pi/2$ (c) changes by $\pi/2$ (d) changes by π

23. In a Young's double slit interference expriment, the slits are at a distance 2L from each other and the screen is at a distance D from the slits. If a glass slab of refractive index μ and thickness d is placed in the path of one of the beams, the minimum value of d for the central fringe to be dark is **[NET Dec. 2011]**

(a) $\frac{\lambda D}{(\mu-1)\sqrt{D^2+L^2}}$ (b) $\frac{\lambda D}{(\mu-1)L}$ (c) $\frac{\lambda}{(\mu-1)}$ (d) $\frac{\lambda}{2(\mu-1)}$

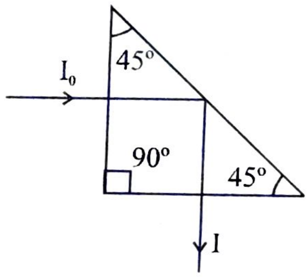
24. Consider three polarizers P_1, P_2 and P_3 placed along an axis as shown in the Figure. **[NET Dec. 2011]**



The pass axis of P_1 and P_3 are at right angles to each other while the pass axis of P_2 makes an angle θ with that of P_1. A beam of unpolarized light of intensity I_0 is incident on P_1 as shown. The intensity of light emerging from P_3 is **[NET Dec. 2011]**

(a) 0 (b) $\frac{I_0}{2}$ (c) $\frac{I_0}{8}\sin^2 2\theta$ (d) $\frac{I_0}{4}\sin^2 2\theta$

25. Circularly polarized light with intensity I_0 is incident normally on a glass prism as shown in the figure. The index of refraction of glass is 1.5. The intensity I of light emerging from the prism is: **[NET June 2011]**



(a) I_0 (b) $0.96\ I_0$ (c) $0.92\ I_0$ (d) $0.88\ I_0$.

26. If $\vec{E}$ and $\vec{B}$ are the electric and magnetic fields respectively, identify the Lorentz invariant quantity from the following. **[NET June 2009]**

(a) $\vec{E}^2\ \vec{B}$ (b) $|\vec{E}\times\vec{B}|^2$ (c) $\vec{E}^2 - c^2\vec{B}^2$ (d) $\vec{E}^2 + c^2\vec{B}^2$

27. Which of the following quantities is Lorentz invariant?

(a) $|E\times B|^2$ (b) $|E|^2 - |B|^2$ (c) $|E|^2 + |B|^2$ (d) $|E|^2\,|B|^2$

28. An observer in an initial frame that a point P the electric field vanishes but the magnetic field does not. This implies that in any other initial frame the electric field $\vec{E}$ and the magnetic field $\vec{B}$ satisfy **[JEST 2012]**

(a) $|\vec{E}|^2 = |B|^2$ (b) $\vec{E}.\vec{B} = 0$ (c) $\vec{E}\times\vec{B} = 0$ (d) $\vec{E} = 0$

29. Consider the electric and magnetic fields of an accelerating charge. How should the fields vary with r (the retarded distance) for the poynting vector to remain finite at arbitrary large distances?

(a) $1/r$ (b) $1/r^2$ (c) r (d) r^2

30. In a given frame of refrence, it is found that the electric field $\vec{E}(\vec{r},t)$ and the magnetic field $\vec{B}(\vec{r},t)$ are perpendicular to each other at all points, i.e., $\vec{E}(\vec{r},t).\vec{B}(\vec{r},t) = 0$. If the fields observed in any other inertial frame are $\vec{E}'$ and $\vec{B}'$, then **[NET 2008]**

(a) $\vec{E}'//\vec{B}'$ at all points (b) $\vec{E}'.\vec{B}' < 0$ at all points

(c) $\vec{E}'.\vec{B}' > 0$ (d) $\vec{E}'.\vec{B}' = 0$

31. Consider the following three independent cases : **[GATE 2005]**

(i) Particle A of charge +q moves in free space with a constant velocity υ (υ << speed of light)

(ii) Particle B of charge +q moves in free space in a circle of radius R with same speed υ as in case (i)

(iii) Particle C having charge –q moves as in case (ii)

If the powers radiated by A, B and C are P_A, P_B and P_C respectively, then :

(a) $P_A = 0, P_B > P_C$ (b) $P_A = 0, P_B = P_C$

(c) $P_A > P_B > P_C$ (d) $P_A = P_B = P_C$

32. The electromagnetic field due to a point charge must be described by Lienard Weichert potentials when **[GATE 2007]**
(a) the point charge is highly accelerated
(b) the electric and magnetic fields are not perpendicular
(c) the point charge is moving with velocity close to that of light.
(d) the calculation is done for the radiation zone, i.e. far away from the charge.

33. The electric and magnetic fields caused by an accelerated charged particle are found to scale as $E \propto r^{-n}$ and $B \propto r^{-m}$ at large distances. What are the values of n and m? **[JEST 2013]**

(a) $n = 1, m = 2$ (b) $n = 2, m = 1$ [✓ (c) $n = 1, m = 1$] (d) $n = 2, m = 2$

34. A circular loop of wire of radius a carries an oscillating current I of frequency ω. The electric and magnetic fields at distance r much larger than $a\left(r >> a\right)$ very as

(a) $E \propto \frac{1}{r},\ B \propto \frac{1}{r^2}$ (b) $E \propto \frac{1}{r^2},\ B \propto \frac{1}{r^2}$ (c) $E \propto \frac{1}{r},\ B \propto \frac{1}{r}$ (d) $E \propto \frac{1}{r^2},\ B \propto \frac{1}{r}$

35. An oscillating current $I(t) = I_0 \exp(-i\omega t)$ flows in the direction of the y-axis through a thin metal sheet of area $1.0\,\text{cm}^2$ kept in the xy-plane. The rate of total energy radiated per unit area from the surfaces of the metal sheet at a distance of 100m is **[NET June 2013]**

(a) $I_0\omega/(12\pi\varepsilon_0 c^3)$ (b) $I_0^{\,2}\omega^2/(12\pi\varepsilon_0 c^3)$ (c) $I_0^{\,2}\omega/(12\pi\varepsilon_0 c^3)$ (d) $I_0\omega^2/(24\pi\varepsilon_0 c^3)$

36. A non-relativistic particle of mass m and charge e, moving with a velocity $\vec{v}$ and acceleration $\vec{a}$, emits radiation of intensity I. What is the intensity of the radiation emitted by a particle of mass $m/2$, charge $2e$, velocity $\vec{v}/2$ and acceleration $2\vec{a}$? **[NET Dec. 2014]**

[✓ (a) $16\,I$] (b) $8\,I$ (c) $4\,I$ (d) $2\,I$

37. The electric and the magnetic fields $\vec{E}(z,t)$ and $\vec{B}(z,t)$, respectively corresponding to the scalar potential $\phi(z,t) = 0$ and vector potential $\vec{A}(z,t) = \hat{i}tz$ are **[GATE 2012]**

(a) $\vec{E} = \hat{i}z$ and $\vec{B} = -\hat{j}t$ (b) $\vec{E} = \hat{i}z$ and $\vec{B} = \hat{j}t$ (c) $\vec{E} = -\hat{i}z$ and $\vec{B} = -\hat{j}t$ (d) $\vec{E} = -\hat{i}z$ and $\vec{B} = \hat{j}t$

38. An electro-magnetic field is defined by a scalar potential $\phi(\vec{r}, t) = 0$ and vector potential $\vec{A}(\vec{r}, t) = \frac{1}{4\pi\varepsilon_0}\frac{qt}{r^2}\hat{r}$.

The corresponding electric field is :

(a) $\vec{E} = 0$ (b) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (c) $\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$ (d) $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{\theta}$

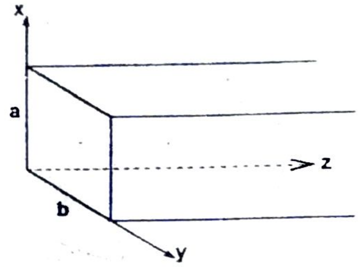
39. The angular distribution of the average power radiated from a short dipole antenna of length d, is dependent on d and polar angle θ. This dependence is proportional to

(a) $\sin^2\theta$ (b) $d\sin^2\theta$ (c) $d^2\sin^2\theta$ (d) $d\sin\theta$

40. A rod of length L carries a total charge Q distributed uniformly. If this is observed in a frame moving with a speed v along the rod, the charge per unit length (as measured by the moving observer) is **[NET June 2015]**

(a) $\frac{Q}{L}\left(1-\frac{v^2}{c^2}\right)$ (b) $\frac{Q}{L}\sqrt{1-\frac{v^2}{c^2}}$ (c) $\frac{Q}{L\sqrt{1-\frac{v^2}{c^2}}}$ (d) $\frac{Q}{L\left(1-\frac{v^2}{c^2}\right)}$

41. The magnetic field of the TE_{11} mode of a rectangular waveguide of dimensions $a \times b$ as shown in the figure given by $H_z = H_0 \cos(0.3\pi x)\cos(0.4\pi y)$, where x and y are in cm. **[NET June 2011]**



A. The dimensions of the waveguide are

(a) a = 3.33 cm, b = 2.50 cm (b) a = 0.40 cm, b = 0.30 cm

(c) a = 0.80 cm, b = 0.60 cm (d) a = 1.66 cm, b = 1.25 cm

B. The entire range of frequencies f for which the TE_{11} mode will propagate is:

(a) 6.0 GHz < f < 7.5 GHz (b) 7.5 GHz < f < 9.0 GHz

(c) 7.5 GHz < f < 12.0 GHz (d) 7.5 GHz < f

42. For a wave propagating in an air filled metallic rectangular waveguide, the frequency and the wave vector are related as (c is the speed of light and ω_c is the cut off frequency)

(a) $c^2k^2 = \omega^2 + \omega_c^2$ (b) $c^2k^2 = \omega^2$ (c) $c^2k^2 = \omega^2 - \omega_c^2$ (d) $c^2k^2 = \sqrt{\omega^4 - \omega_c^4}$

43. An electromagnetic wave propagating along the z-direction in a rectangular waveguide in the TE mode is characterized by

(a) $E_z = 0, H_z \neq 0$ (b) $H_z = 0, E_z \neq 0$ (c) $E_z = 0, H_z = 0$ (d) $E_z \neq 0, H_z \neq 0$

44. In a distortionless transmission line the attenuation constant α is frequency independent while the propagation constant depends linearly on frequency. If R, L, C and G denote the transmission line parameters, for the distortion, less line

(a) $RG = \frac{1}{\sqrt{LC}}$ (b) $\frac{R}{L} = \frac{C}{G}$ (c) $R = \sqrt{\frac{L}{C}}$ (d) $\frac{R}{L} = \frac{G}{C}$

45. The values of the electric and magnetic fields in a particular reference frame (in Gaussian units) are $\boldsymbol{E} = 3\hat{x} + 4\hat{y}$ and $\boldsymbol{B} = 3\hat{z}$, respectively. An inertial observer moving with respect to this frame measures the magnitude of the electric field to be $|\boldsymbol{E}'| = 4$. The magnitude of the magnetic field $|\boldsymbol{B}'|$ measured by him is

(a) 5 (b) 9 (c) 0 (d) 1 **[NET June 2016]**

46. A wave~~length~~guide has a square cross-section of side $2a$. For the TM modes of wavevector k, the transverse electromagnetic modes are obtained in terms of a function $\psi(x, y)$ which obeys the equation

$$\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \left(\frac{\omega^2}{c^2} - k^2\right)\right]\psi(x, y) = 0$$

with the boundary condition $\psi(\pm a, y) = \psi(x, \pm a) = 0$. The frequency ω of the lowest mode is given by

(a) $\omega^2 = c^2\left(k^2 + \frac{4\pi^2}{a^2}\right)$ (b) $\omega^2 = c^2\left(k^2 + \frac{\pi^2}{a^2}\right)$

(c) $\omega^2 = c^2\left(k^2 + \frac{\pi^2}{2a^2}\right)$ (d) $\omega^2 = c^2\left(k^2 + \frac{\pi^2}{4a^2}\right)$

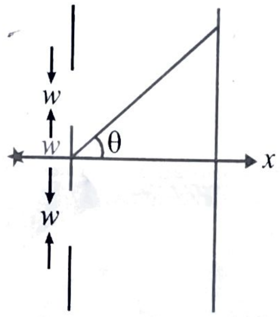
47. An unpolarized ray of light in a medium with refractive index n_1 is incident on a plane glass surface with refractive index $n_2 (n_2 > n_1)$. The intensity of the reflected light is minimum when the angle of incidence i is given by

(a) $\tan(i) = n_1 / n_2$ (b) $\tan(i) = n_2 / n_1$ (c) $\tan(i) = 1 / n_1 n_2$ (d) $\tan(i) = n_1 n_2$

48. A particle with charge $-q$ moves with a uniform angular velocity ω in a circular orbit of radius a in the xy-plane, around a fixed charge $+q$, which is at the centre of the orbit at (0, 0, 0). Let the intensity of radiation at the point (0, 0, R) be I_1 and at (2R, 0, 0) be I_2. The ratio I_2/I_1, for $R \gg a$, is

(a) 4 (b) $\frac{1}{4}$ (c) $\frac{1}{8}$ (d) 8 **[NET Dec. 2016]**

49. A screen has two slits, each of width w, with their centres at a distance $2w$ apart. It is illuminated by a monochromatic plane wave travelling along the x-axis. **[NET Dec. 2016]**



The intensity of the interference pattern, measured on a distant screen, at an angle $\theta = n\lambda/w$ to the x-axis is

(a) zero for $n = 1, 2, 3...$ (b) maximum for $n = 1, 2, 3...$

(c) maximum for $n = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ (d) zero for $n = 0$ only

50. Light is incident from a medium of refractive index $n = 1.5$ onto vacuum. The smallest angle of incidence for which the light is not transmitted into vacuum is ________ degrees. (up to two decimal places). **[GATE 2017]**

51. Consider magnetic vector potential $\vec{A}$ and scalar potential Φ which define the magnetic field $\vec{B}$ and electric field $\vec{E}$. If one adds $-\vec{\nabla}\lambda$ to $\vec{A}$ for a well defined λ, then what should be added to Φ so that $\vec{E}$ remains unchanged up to an arbitrary function of time, $f(t)$? **[JEST 2017]**

(a) $\frac{\partial \lambda}{\partial t}$ (b) $-\frac{\partial \lambda}{\partial t}$ (c) $\frac{1}{2}\frac{\partial \lambda}{\partial t}$ (d) $-\frac{1}{2}\frac{\partial \lambda}{\partial t}$

52. Two coherent monochromatic light beams of intensities I and 4I are superimposed. The maximum and minimum possible internsities in the resulting beam are

(a) 3I and I (b) 5I and 3I (c) 7I and 5I (d) 9I and I

53. A beam of light polarized in the x-direction is travelling in the z-direction. It passes through a polarizer and reaches an analyzer. The polarization axis of the analyzer can only be rotated in the x-y plane. It is found that the intensity is 3 times smaller when the polarization axis of the analyzer is in the y direction as compare to that in the x-direction. The angle between the polarization axis of the polarizer and the x-axis is

(a) 30° (b) 45° (c) 60° (d) 90°

54. Unpolarized light is incident on a combination of a polarizer, a $\lambda/2$ plate and a $\lambda/4$ plate kept one after the other. What will be the output polarization for the following configurations?

Configuration 1: Axes of the polarizer, the $\lambda/2$ plate and the $\lambda/4$ plate are all parallel to each other.
Configuration 2: The $\lambda/2$ plate is rotated by 45° with respect to configuration 1
Configuration 3: The $\lambda/4$ plate is rotated by 45° with respect to configuration 1
(a) Linear for configuration 1, linear for configuration 2, circular for configuration 3
(b) Linear for configuration 1, circular for configuration 2, circular for configuration 3
(c) Circular for configuration 1, circular for configuration 2, circular for configuration 3
(d) Circular for configuration 1, linear for configuration 2, circular for configuration 3

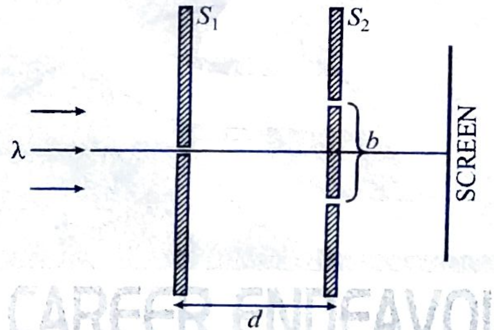
55. Unpolarized light of intensity I_0 passes through a polarizer P_1. The light coming out of the polarizer falls on a quarter-wave plate with its optical axis at 45° with respect to the polarization axis of P_1 and then passes through another polarizer P_2 with its polarization axis perpendicular to that of P_1. The intensity of the light coming out of P_2 is I. The ratio I_0/I is ____________

(Specify your answer to two digits after the decimal point)

56. An electron is decelerated at a constant rate starting from an initial velocity u (where $u \ll c$) to $u/2$ during which it travels a distance s. The amount of energy lost to radiation is **[NET June 2017]**

(a) $\dfrac{\mu_0 e^2 u^2}{3\pi mc^2 s}$ (b) $\dfrac{\mu_0 e^2 u^2}{6\pi mc^2 s}$ (c) $\dfrac{\mu_0 e^2 u}{8\pi mcs}$ (d) $\dfrac{\mu_0 e^2 u}{16\pi mcs}$

57. The figure below describes the arrangement of slits and screens in a Young's double slit experiment. The width of the slit in S_1 is a and the slits in S_2 are of negligible width. **[NET June 2017]**



If the wavelength of the light is λ, the value of d for which the screen would be dark is

(a) $b\sqrt{\left(\dfrac{a}{\lambda}\right)^2 - 1}$ (b) $\dfrac{b}{2}\sqrt{\left(\dfrac{a}{\lambda}\right)^2 - 1}$ (c) $\dfrac{a}{2}\left(\dfrac{b}{\lambda}\right)^2$ (d) $\dfrac{ab}{\lambda}$

58. In an intertial frame S, the magnetic vector potential in a region of space is given by $\vec{A} = az\hat{i}$ (where a is a constant) and the scalar potential is zero. The electric and magnetic fields seen by an inertial observer moving with a velocity $v\hat{i}$ with respect to S, are respectively. [In the following $\gamma = \dfrac{1}{\sqrt{1 - v^2/c^2}}$].

[NET Dec. 2017]

(a) 0 and $\gamma a\hat{j}$ (b) $-va\hat{k}$ and $\gamma a\hat{i}$ (c) $v\gamma a\hat{k}$ and $v\gamma a\hat{j}$ (d) $v\gamma a\hat{k}$ and $\gamma a\hat{j}$

59. In the rest frame S_1 of a point particle with electric charge q_1, another point particle with electric charge q_2 moves with a speed v parallel to the x-axis at a perpendicular distance l. The magnitude of the electromagnetic force felt by q_1 due to q_2 when the distance between them is minimum, is

[In the following $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$]. **[NET Dec. 2017]**

(a) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{\gamma l^2}$

(b) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{\gamma q_1 q_2}{l^2}$

(c) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{\gamma q_1 q_2}{l^2}\left(1+\dfrac{v^2}{c^2}\right)$

(d) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{\gamma l^2}\left(1+\dfrac{v^2}{c^2}\right)$

60. The characteristic impedance of a co-axial cable is independent of the **[TIFR 2018]**

(a) Core diameter

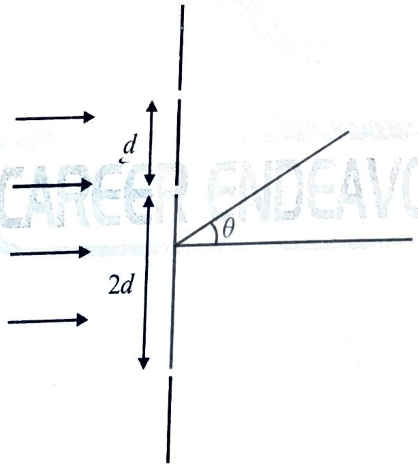
(b) Outer diameter

(c) Length of the cable

(d) Dielectric medium between the core and the outer mesh

61. Consider a dipole antenna which length ℓ, charge q and frequency ω. The power emitted by the antenna at a large distance r is P. Now suppose the length ℓ is increased to $\sqrt{2}\,\ell$, the charge is increased to $\sqrt{3}\,q$ and the frequency is increased to $\sqrt{5}\,\omega$. By what factor is the radiated power increased? **[TIFR 2018]**

62. The following configuration of three identical narrow slits are illuminated by monochromatic light of wavelength λ (as shown in the figure below). The intensity is measured at an angle θ (where θ is the angle with the incident beam) at a large distance from the slits. If $\delta = \dfrac{2\pi d}{\lambda}\sin\theta$, the intensity is proportional to



(a) $2\cos\delta + 2\cos 2\delta$

(b) $3 + \dfrac{1}{\delta^2}\sin^2 3\delta$ **[NET June 2018]**

(c) $3 + 2\cos\delta + 2\cos 2\delta + 2\cos 3\delta$

(d) $2 + \dfrac{1}{\delta^2}\sin^2 3\delta$

63. The electric field $\vec{E}$ and the magnetic field $\vec{B}$ corresponding to the scalar and vector potentials, $V(x, y, z, t) = 0$ and $\vec{A}(x, y, z, t) = \frac{1}{2}\hat{k}\mu_0 A_0 (ct - x)$, where A_0 is a constant, are **[NET June 2018]**

(a) $\vec{E} = 0$ and $\vec{B} = \frac{1}{2}\hat{j}\,\mu_0 A_0$ (b) $\vec{E} = -\frac{1}{2}\hat{k}\,\mu_0 A_0 c$ and $\vec{B} = \frac{1}{2}\hat{j}\,\mu_0 A_0$

(c) $\vec{E} = 0$ and $\vec{B} = -\frac{1}{2}\hat{i}\,\mu_0 A_0$ (d) $\vec{E} = \frac{1}{2}\hat{k}\,\mu_0 A_0 c$ and $\vec{B} = -\frac{1}{2}\hat{i}\,\mu_0 A_0$

64. In the region far from a source, the time dependent electric field at a point (r, θ, ϕ) is

$$\vec{E}(r, \theta, \phi) = \hat{\phi}\, E_0\, \omega^2 \left(\frac{\sin\theta}{r}\right) \cos\left[\omega\left(t - \frac{r}{c}\right)\right]$$

where ω is angular frequency of the source. The total power radiated (average over a cycle) is

(a) $\frac{2\pi}{3}\frac{E_0^2\omega^4}{\mu_0 c}$ (b) $\frac{4\pi}{3}\frac{E_0^2\omega^4}{\mu_0 c}$ (c) $\frac{4}{3\pi}\frac{E_0^2\omega^4}{\mu_0 c}$ (d) $\frac{2}{3}\frac{E_0^2\omega^4}{\mu_0 c}$ **[NET June 2018]**

65. A hollow waveguide supports transverse electric (TE) modes with the dispersion relation $k = \frac{1}{c}\sqrt{\omega^2 - \omega_{mn}^2}$, where ω_{mn} is the mode frequency. The speed of flow of electromagnetic energy at the mode frequency is

(a) c (b) ω_{mn}/k (c) 0 (d) ∞ **[NET June 2018]**

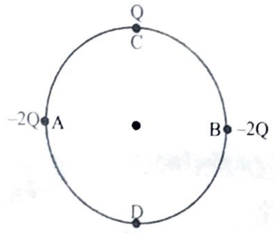
CSIR-UGC-NET/JRF | GATE PHYSICS

Assignment-09: Electromagnetic Theory

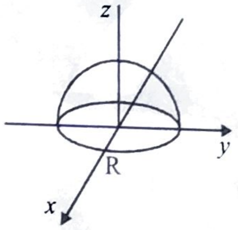
1. A charge Q is divided into two parts and placed some distance apart. What should be values of charges on the two parts so that force between them is maximum.

2. A point charge $q = 50\mu c$ is located in the x-y plane at the point of the position vector $\vec{r}_0 = 2\hat{i} + 3\hat{j}$. Electric force on a point charge $q' = 20\mu c$ placed at point $\vec{r} = 8\hat{i} - 5\hat{j}$ is

3. Three point charges are placed on the circumference of a circle as shown in the figure. What charge should be placed at D so that net force on C becomes zero?

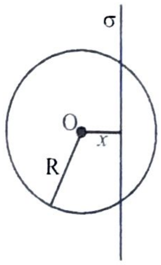


4. A closed hemispherical bowl as shown in the figure, is placed in an electric field given by $\vec{E} = (r\cos\theta)\hat{r} + (r\sin\theta)\hat{\theta} + (r\sin\theta\cos\phi)\hat{\phi}$. Calculate the electric flux passing through the hemisphere.



5. An electric field $\vec{E} = \alpha\hat{r} + f(\theta)\hat{\phi}$ exists in space. Total flux through a sphere centered at origin will
(a) depend on $f(\theta)$
(b) not dependent on radius of sphere
(c) depend both on $f(\theta)$ and radius
(d) depend on radius but not on $f(\theta)$

6. A plane sheet of surface charge density σ is inserted into a sphere of radius R. The perpendicular distance of the plane from the centre is x. Calculate the flux passing through the sphere.



7. Given that $\vec{E} = zs\cos^2\phi\,\hat{z}$ N/c. Calculate the charge density at $(1, \pi/4, 3)$ and the total charge enclosed by the cylinder of radius 1m with $-2 \le z \le 2$m.

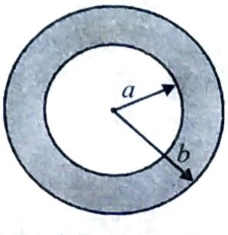
8. If $\vec{E} = (2y^2 + z)\hat{x} + 4xy\hat{y} + x\hat{z}$ N/c, find
(a) The volume charge density at $(-1, 0, 3)$
(b) The flux through the cube defined by $0 \le x \le 1, 0 \le y \le 1, 0 \le z \le 1$
(c) The total charge enclosed by the cube

9. A sphere of radius R contains space charge density $\rho(r) = A(R-r)$ for $0 < r < R$. The total electr
charge inside the sphere is Q.
(a) Express A in terms of Q and R
(b) Find the electric field inside and outside the sphere

10. A long cylinder carries a charge density that is proportional to the distance from the axis: $\rho = ks$, for som
constant k. Find the electric field inside this cylinder.

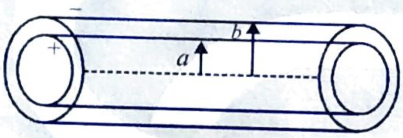
11. Find the electric field a distance s from an infinity long straight wire, which carries a uniform line charge

12. A hollow spherical shell carries charge density $\rho = \frac{k}{r^2}$ in the region $a \le r \le b$ (fig.). Find the electric fiel
in the three regions (i) $r < a$ (ii) $a < r < b$, (iii) $r > b$. Also find total charge on the spherical shell.



13. An infinite plane carries a uniform surface charge σ. Find its electric field.

14. A long coaxial cable (Fig.) carries a uniform volume charge density ρ on the inner cylinder (radius a), and
a uniform surface charge density on the outer cylindrical shell (radius b). This surface charge is negative and
of just the right magnitude so that the cable as a whole is electrically natural. Find the electric field in each
of the three regions: (i) inside the inner cylinder ($s < a$), (ii) between the cylinders ($a < s < b$), (iii) outside
the cable ($s>b$).



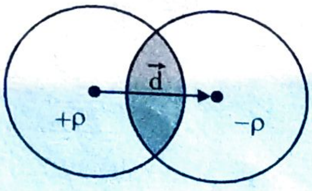
15. A spherical charge distribution is given by

$$\rho = \rho_0\left(1 - \frac{r^2}{a^2}\right) \qquad \text{for } r \le a,$$

$$\rho = 0 \qquad \text{for } r > a$$

where a is the sphere. Find electric field intensity at a distance r from the centre when $r > a$ and when
$r < a$. Find the value of r at which electric field is maximum.

16. Imagine overlapping of two solid spheres of same radii and carrying uniform volume charges of densities
ρ and $-\rho$. Calculate electric field in the overlapping region if distance between their centers is d.



17. Charge density on the surface of a hemisphere is $\sigma = \sigma_0 \cos\theta$, if the radius of the hemisphere is R then
find the electric field at this centre of the hemisphere.

18. The electric field in a region is given to be $\vec{E} = ay\hat{i} + bx\hat{j} + cy\hat{k}$. Calculate the values of constants a, b and
c, so that $\vec{E}$ is electrostatic field.

CSIR-UGC-NET/JRF | GATE PHYSICS

Assignment-10: Electromagnetic Theory

1. Find out which electric field is electrostatic?

(a) $\vec{E} = k[xy\hat{x} + 2yz\hat{y} + 3xz\hat{z}]$;   (b) $\vec{E} = k[y^2\hat{x} + (2xy + z^2)\hat{y} + 2yz\hat{z}]$

2. Find the potential inside and outside a spherical shell of radius R which carries a uniform surface charge σ.

3. Find the potential inside and outside a uniformly charged solid sphere whose radius is R and whose total charge is q. Compute the gradient of V in each region, and check that it yields the correct electric field.

4. Find the potential a distance s from an infinitely long straight wire that carries a uniform line charge λ. Compute the gradient of your potential, and check that it yields the correct field.

5. Given the potential $V = \frac{10}{r^2}\sin\theta\cos\phi$ in spherical polar coordinate system.

(a) Find the electric flux density $\vec{E}$ at $(2, \pi/2, 0)$.

(b) Calculate the work done in moving a $10\,\mu C$ charge from point A(1, 30°, 120°) to B(4, 90°, 60°).

6. The potential of the spherical charge distribution is given by

$$V(r,\theta,\phi) = \left(\frac{V_0}{2}\right)\left(3 - \frac{r^2}{R^2}\right) \quad r < R$$

$$= \frac{V_0 R}{r} \qquad r > R$$

where V_0 and R are constants.

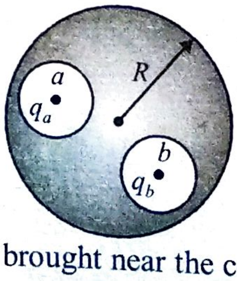
(a) Obtain the corresponding electric field distribution

(b) To what charge distribution would this correspond.

(c) Total charge on the sphere.

7. Determine the potential difference in volts between the points A(2, 0, –3) and B$(1, \frac{\pi}{2}, 7)$ lying in a region having electric field intensity $\vec{E} = \frac{\cos\phi}{s^2}\hat{s} + \frac{\sin\phi}{s^2}\hat{\phi}$ V/m.

8. Two spherical cavities, of radii a and b, are hollowed out from the interior of a (neutral) conducting sphere of radius R shown in figure. At the centre of each cavity a point charge is placed - call these charges q_a and q_b.



(a) Find the surface charges σ_a, σ_b and σ_R

(b) What is the field outside the conductor?

(c) What is the field within each cavity?

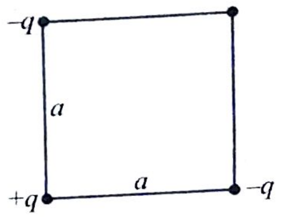
(d) What is the force on q_a and q_b?

(e) Which of these answers would change if a third charge, q_c, were brought near the conductor?

9. Two conducting spheres of charges Q_1 and Q_2 and radius r_1 and r_2 respectively, such that $(r_1 > r_2)$, now these two conductors are connected by a metallic wire. Calculate the potential and charge on two sphere after connection.

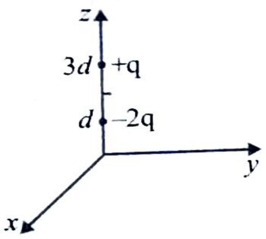
10. (a) Three charges are situated at the corners of a square (side a), as shown in figure. How much work does it take to bring in another charge, $+q$, from far away and place it in the fourth corner?

(b) How much work does it take to assemble the whole configuration of four charges?

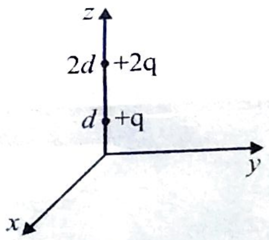


11. Find the energy of a uniformly charged spherical shell of total charge q and radius R.

12. Find the force on the charge $+q$ in figure. (The xy plane is a grounded conductor).



(a)



(b)

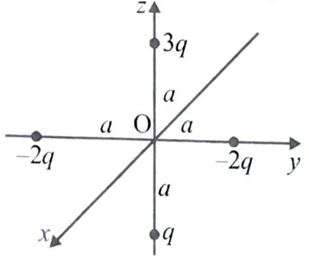
CSIR-UGC-NET/JRF|GATE PHYSICS

Assignment-11: Electromagnetic Theory

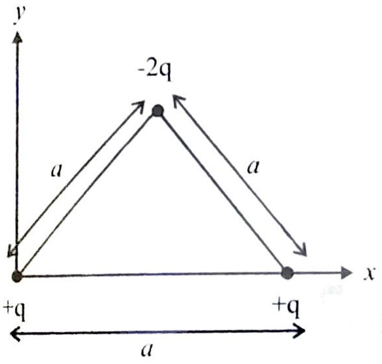
1. An electric dipole with $\vec{p}=p\hat{z}$ C.m is placed at (x, y, z) = (0, 0, 0). If the potential at (0, 0, 1m) is 9V, find the potential at (1m, 0, 1m).

2. A "pure" dipole p is situated at the origin, pointing in the z-direction
(a) What is the force on a point charge q at $(a, 0, 0)$ (Cartesian coordinates)?
(b) What is the force on q at $(0, 0, a)$?
(c) How much work does it take to move q from $(a, 0, 0)$ to $(0, 0, a)$?

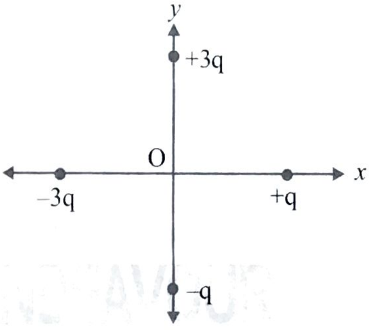
3. Four particles (one of charge q, one of charge $3q$, and two of charge $-2q$) are placed as shown in figure, each a distance a from the origin. Find a simple approximate formula for the potential, valid at points far from the origin. (Express your answer in spherical coordinates).



4. (i)



(ii)



Calculate the dipole moment $(\vec{p})$ of the above charge configurations.

5. A sphere of radius R, centered at the origin, carries charge density $\rho(r,\theta)=k\frac{R}{r^2}(R-2r)\sin\theta$, where k is a constant, and r, θ are the usual spherical coordinates. Find the monopole moment and dipole moment for this charge distribution.

6. The electric potential of a grounded conducting sphere of radius R in a uniform electric field $E_0\hat{k}$ along z-direction is given by the following expression

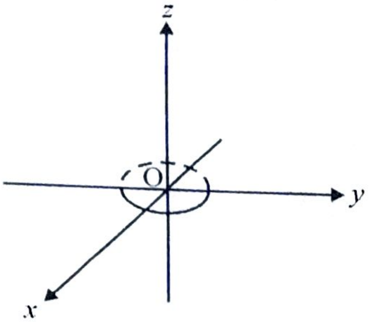
$$\phi(r,\theta)=-E_0 r\cos\theta+\frac{E_0R^3\cos\theta}{r^2}$$

where 'r' is the distance from the centre of the sphere and θ is angle the radius vector makes with the z-axis.
(a) What is dipole moment aquired by the sphere?
(b) Calculate the radial and tangential component of the electric field on the surface of the sphere
(c) What is the surface charge density on the sphere?

7. A circular disc of radius a on the xy plane has a surface charge density $\sigma = \frac{\sigma_0 r\cos\phi}{2}$, calculate th dipole moment of this charge distribution.

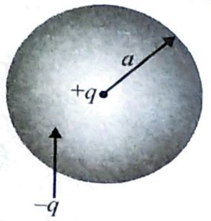
8. A thin insulating rod, running from $z = -a$ to $z = +a$, carries the indicated line charges. In each case, find the dipole moment and leading term in the multipole expansion of the potential: $\lambda = k\cos(\pi z/2a)$, where k is a constant.

9. A thin circular ring of radius R lies in the xy-plane with its centre at the origin of coordinates O (see figure). the ring has a uniform linear change density λ.



Find the electric dipole moment $\vec{p}$, about the point O, of the charge distribution.

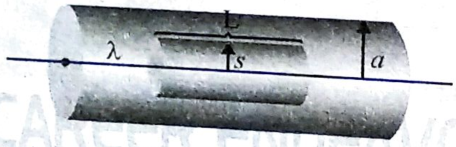
10. A primitive model for an atom consists of a point nucleus $(+q)$ surrounded by a uniformly charged spherical could $(-q)$ of radius a shown in figure. Calculate the atomic polarizability of such an atom.



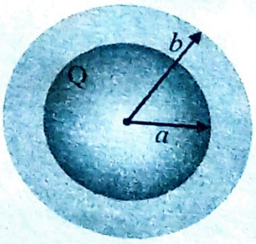
11. A sphere of radius R carries a polarization $\vec{P}(r) = kr$, where k is a constant and r is the vector from the centre.

(a) Calculate the bound charges σ_b and ρ_b.(b) Find the field inside and outside the sphere.

12. A long straight wire, carrying uniform line charge λ, is surrounded by rubber insulation out to a radius a shown in figure. Find the electric displacement.



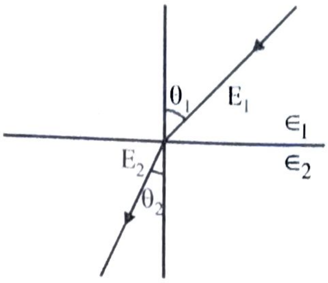
13. A metal sphere of radius a carries a charge Q shown in figure. It is surrounded, out to radius b, by linear dielectric material of permittivity ϵ. Find the potential at the center (relative to infinity).



14. A dielectric sphere of radius R has polarization $\vec{P} = kr^2\vec{r}$. Calculate electric field inside and outside the sphere. Also calculate surface and volume bound charge densities and energy of the dielectric sphere.

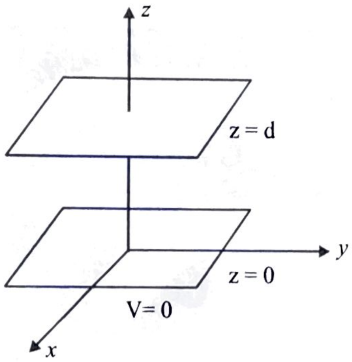
15. A point charge q is imbedded at the center of a sphere of linear dielectric material (with susceptibility χ_e and radius R). Find the electric field, the polarization, and the bound charge densities, ρ_b and σ_b. What is the total bound charge on the surface? Where is the compensating negative bound charge located?

16. At the interface between one linear dielectric and another the electric field lines bend as shown in figure. Show that $\tan\theta_2 / \tan\theta_1 = \epsilon_2 / \epsilon_1$ assuming there is no free charge at the boundary.

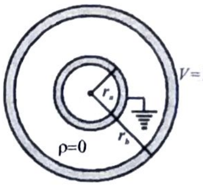


17. The region $z > 0$ of a cartesian coordinate system contains a linear isotropic dielectric of dielectric constant 2.0. The region $z < 0$ is the free space. A free space charge density of $5nC/m^2$ is at the inteface $z = 0$. If the displacement vector in the dielectric is $\vec{D}_2 = 3\hat{x} + 4\hat{y} + 6\hat{z}\ nC/m^2$, find the corresponding displacement vector $\vec{D}_1$ is free space.

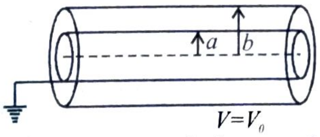
18. Consider the parallel conductors shown in the figure, where V = 0 at z = 0 and V = 100V at z = d. Assuming the region between the plates is charge free. Calculate the potential and electric field between the conductors.



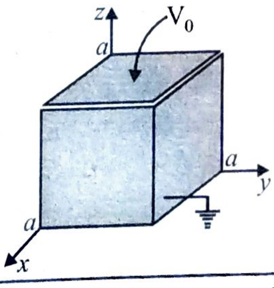
19. Consider two concentric spherical conducting shells at the origin. The outer radius of the inner shell is r_a and inner radius of the outer shell is r_b. If charge density $\rho = 0$ in the region $r_a < r < r_b$. V = 0 at $r = r_a$ and $V = V_0$ at $r = r_b$. Find V in the region $r_a < r < r_b$ by solving Laplace's equation.



20. Two coaxial concentric cylinder is of radius a and b, if the inner one grounded and outer is at potential V_0. Find potential and electric field between the cylinders by using the laplace equation. Also find capacitance per unit length of the cylinders.



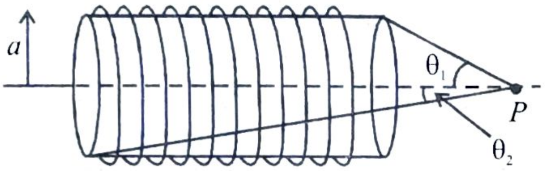
21. A cubical box (sides of length a) consists of five metal plates, which are welded together and grounded shown in figure. The top is made of a separate sheet of metal, insulated from the others, and held at a constant potential V_0. Find the potential inside the box.



CSIR-UGC-NET/JRF|GATE PHYSICS

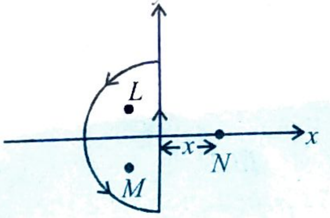
Assignment-12: Electromagnetic Theory

1. Find the magnetic field at pint P on the axis of a tightly wound solenoid (helical coil) consisting of n truns per unit length wrapped around a cylinderical tube of radius a and carrying current I. Express your answer in terrms of θ_1 and θ_2 . Consider the turns to be essentially circular, and use the result. What is the field on the axis of an infinite solenoid (infinite in both directions)?



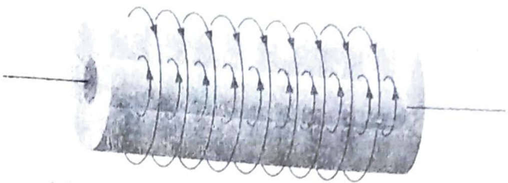
2. Find the magnetic field a distance 's' from a long straight wire , carrying a steady current I.
3. Find the magnetic field at a distance z above an infinite uniform surface current $\mathbf{K} = K\hat{x}$, flowing over the xy plane.
4. A steady current I flows down a long cylindrical wire of radius 'a'. Find the magnetic field, both inside and outside the wire, if
   (a) The current is uniformly distributed over the outside surface of the wire.
   (b) The current is distributed in such a way that J is proportional to s, the distance from the axis.
5. A long wire has a circular cross-section with radius a. The current density in the wire is $J(r) = J_0\left(\frac{a^2 - r^2}{a^2}\right)$, where '$r$' is the distance from the axis. Calculate the magnetic field at an arbitrary point inside or outside the wire.
6. Consider two in finitely long wires parallel to the z-axis carrying the same current I. One wire passes thorugh the point L with coordinates (–1, 1) and the other through M with coordinates (–1, –1) in the x-y plane as shown in the figure. The direction of the current in the both the wires is in the positive z-direction.

   (a) Find the value of $\oint\limits_{0} \vec{B}\cdot d\ell$ along the semi circular closed path of radius 2 units shown in figure

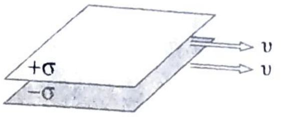


   (b) A third long wire carrying current I and also perpendicular to the xy plane is placed at a point N with coordinates (x, 0) so that the magnetic field at the origin is doubled. Find the x and the direction of the current in third wire.

7. Two long coaxial solenoids each carry current I, but in opposite directions, as shown in figure. The inner solenoid (radius a) has n_1 turns per unit length, and the outer one (radius b) has n_2. Find B in each of the three regions: (i) inside the inner solenoid, (ii) between them, and (iii) outside both.



8. A large parallel-plate capacitor with uniform surface charge σ on the upper plate and $-\sigma$ on the lower is moving with a constant speed v, as shown in figure.



(a) Find the magnetic field between the plates and also above and below them.
(b) Find the magnetic force per unit area on the upper plate, including its direction.
(c) At what speed v would the magnetic force balance the electrical force?

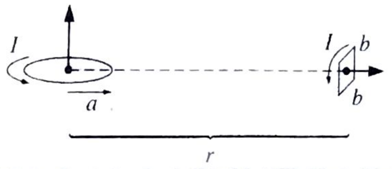
9. Find the vector potential of an infinite solenoid with n turns per unit length, radius R, and current I.

10. Find the magnetic vector potential of a finite segment of straight wire, carrying a current I.

11. What current density would produce the vector potential, $\mathbf{A} = k\hat{\phi}$ (where k is a constant), in cylindrical coordinates?

12. Find magnetic vector potential of a current carrying coil at a distance z above the centre having current z and radius R.

13. Calculate the torque exerted on the square loop shown in figure, due to the circular loop (asumme r is much larger than a or b). If the square loop is free to rotate, what will its equilibrium orientation be?



14. A long circular cylinder of radius R carries a magnetization $\mathbf{M} = ks^2\hat{\phi}$, where k is a constant, s is the distance from the axis, and $\hat{\phi}$ is the usual azimuthal unit vector. Find the magnetic field due to **M**, for points inside and outside the cylinder.

15. A long copper rod of radius R carries a uniformly distributed (free) current I. Find the H inside and outside the rod.

16. An infinitely long cylinder, of radius R, carries a 'frozen-in' magnetization, parallel to the axis.

$$\mathbf{M} = ks^2\hat{z}$$

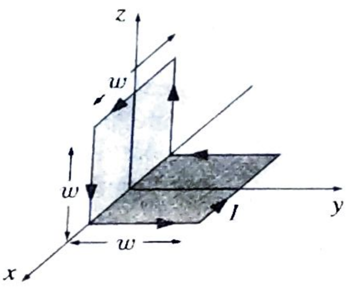
where k is a constant and s is the distance from the axis, there is no free curent anywhere. Find the magnetic field inside and outside the cylinder by two different methods.
(a) locate the bound currents, and calculate the field they produce.
(b) use Ampere's law (in the form of equation) to find H, and then get B.

17. At the interface between two linear magnetic material the magnetic field lines bend. Sho

$\frac{\tan\theta_2}{\tan\theta_1} = \frac{\mu_2}{\mu_1}$, assuming there is no free current at the boundary.

18. Find the magnetic dipole moment of the 'bookend-shaped' loop shown in figure below. All side

length w, and it carries a current.

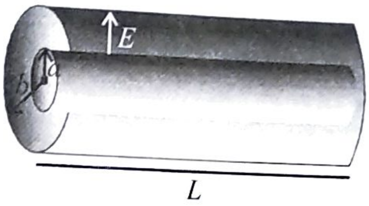


CAREER ENDEAVOUR
Best Institute for IIT-JAM, NET & GATE

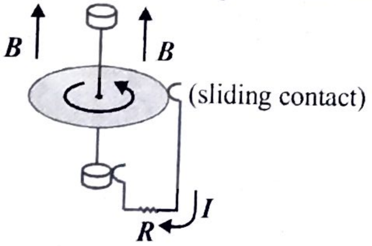
CSIR-UGC-NET/JRF|GATE PHYSICS

Assignment-13: Electromagnetic Theory

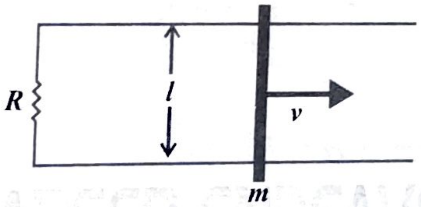
1. Two long cylinders (radii a and b) are separated by material of conductivity σ. If they are maintained at a potential difference V, what current flows from one to the other, in a length L?



2. A metal disk of radius 'a' rotates with angular velocity ω about a vertical axis, through a uniform field **B**, pointing up. A circuit is made by connecting one end of a resistor to the axle and the other end to a sliding contact, which touches the outer edge of the disk. Find the current in the resistor.



3. A metal bar of mass 'm' slides frictionlessly on two parallel conducting rails a distance l apart. A resistance R is connected across the rails and a uniform magnetic field **B**, pointing into the page, fills the entire region.

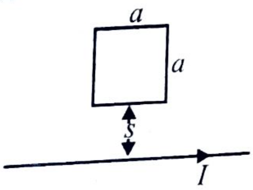


(a) If the bar moves to the right at speed v, what is the current in the resistor? In what direction does it flow?

(b) What is the magnetic force on the bar? In what direction?

(c) If the bar starts out with speed v_0 at time $t = 0$, and is left to slide, what is its speed at a later time t?

4. A square loop of wire (side a) lies on a table, a distance s from a very long straight wire, which carries a current I, as shown in figure below.

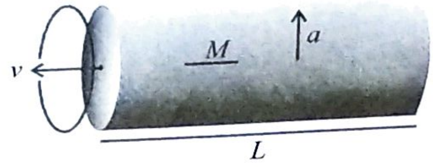


(a) Find the flux of **B** through the loop

(b) If someone now pulls the loop directly away from the wire, at speed v, what emf is generated? In what direction (clockwise or counterclockwise) does the current flow?

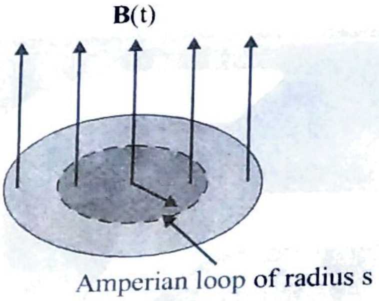
(c) What if the loop is pulled to the right at speed v, instead of away?

5. A long cylindrical magnet of length L and radius a carries a uniform magnetization M parallel to i axis. It passes at constant velocity v through a circular wire ring of slightly larger diameter. Grap the emf induced in the ring, as a function of time.

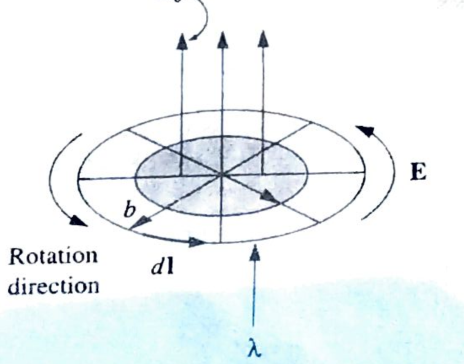


6. A square loop of wire, with sides of length a, lies in the first quadrant of the xy plane, with one corne at the origin. In this region there is a non uniform time-dependent magnetic field $\vec{B}(y,t) = ky^3t^2\hat{z}$ (where k is a constant). Find the emf induced in the loop.

7. A uniform magnetic field $\vec{B}(t)$, pointing straight up, fills the shaded circular region of figure. If $\vec{B}$ is changing with time, what is the induced electric field?

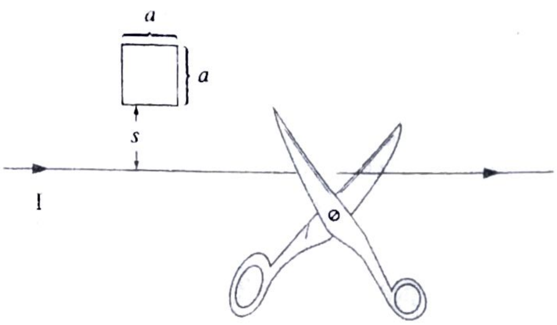


8. A line charge λ is glued onto the rim of a wheel of radius b, which is then suspended horizontally, as shown in figure below. So, that it is free to rotate (the spokes are made of some non-conducting material – wood, maybe). In the central region, out to radius a, there is a uniform magnetic field $\vec{B}_0$, pointing up. Now someone turns the field off. What happens?

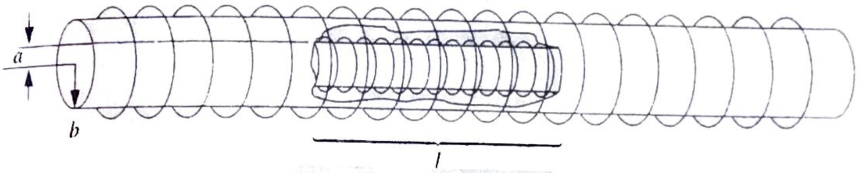


A long solenoid with radius 'a' and 'n' turns per unit length carries a time-dependent current $I(t)$ teh $\hat{\phi}$ direction. Find the electric field (magnitude and direction) at a distance s from the axis th inside the outside the solenoid), in the quasistatic approximation.

10. A square loop, side a, resistance R, lies a distance s from an infinite straight wire that carries current I. Now someone cuts the wire, so that I drops to zero. In what direction does the induced current in the square loop flow, and what total charge passes a given point in the loop during the time this current flow.

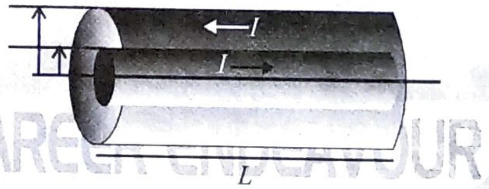


11. A short solenoid (length l and radius a, with n_1 turns per unit length) lies on the axis of a very long solenoid (radius b, n_2 turns per unit length) as shown in figure below. Current I flows in the short solenoid. What is the flux through the long solenoid?



12. Find the self-inductance per unit length of a long solenoid, of radius R, carrying n turns per unit length.

13. A long coaxial cable carries current I (the current flows down the surface of the inner cylinder, radius a, and back along the outer cylinder, radius b) as shown in the figure below. Find the magnetic energy stored in a section of length l.



14. The electric field in the wire of radius 'a' is given by

$$E(s,t)=\frac{\mu_0 I_0 \omega}{2\pi}\sin(\omega t)\,\ell n\left(\frac{a}{z}\right)\hat{z}$$

(a) find the displacement current density J_d

(b) the total displacement current.

(c) compare I_d and I. (what's their ratio?). If the outer cylinder were, say, 2 mm in diameter, how high would the freuquency have to be, for I_d to be 1% of I ?

CSIR-UGC-NET/JRF|GATE PHYSICS

Assignment-14: Electromagnetic Theory

1. An infinite straight wire carries the current

$$I(t)=\begin{cases}0, & for\ t\le 0\\ I_0, & for\ t>0\end{cases}$$

That is, a constant current I_0 is turned on abruptly at $t=0$. Find the resulting electric and magne fields.

2. Suppose the (electrically neutral) yz plane a time-dependent but uniform surface current $K(t)\hat{z}$. Fin the electric and magnetic fields at a height x above the plane if a linearly increasing current is turne on at $t=0$

$$K(t)=\begin{cases}0, & t\le 0\\ \alpha t, & t>0\end{cases}$$

3. In free space $\vec{E}=(10\hat{y}+5\hat{z})\cos(\omega t+2y-4z)$ v/m. Calculate

(a) $\vec{B}$ (b) $\vec{K}$ (c) ω

4. Uniform plane wave in air with

$$\vec{E}=8\cos(\omega t-4x-3z)\hat{y}\text{ v/m}$$

find, $\omega, \vec{K}$ and $\vec{B}$.

5. If $\vec{E}=\hat{i}A\sin(12y)\sin(\alpha z)\cos\omega t$, describes an electric field in free space, what should be the numeri- cal value of α for electric field to satisfy Maxwell's equations, given that the value of ω is 15×10^8 $rad/\sec$.

6. A helium-neon laser beam $(\lambda=632\,nm)$ of intensity $1.0\ \omega/cm^2$ is is travelling along x-axis in vacuum. Find.

(a) Amplitude of E and $\vec{B}$ fields associated with the laser beam.

(b) Expressions for $\vec{E}(x,t)$ and $\vec{B}(x,t)$ if $\vec{E}$ field is polarised along y-direction.

7. Find the fields, and the charge and current distributions, corresponding to

$$V(\vec{r},t)=0,\quad \vec{A}(\vec{r},t)=-\frac{1}{4\pi\varepsilon_0}\frac{qt}{r^2}\hat{r}$$

8. Suppose $V=0$ and $A=A_0\sin(kx-\omega t)\hat{y}$, where A_0, ω and k are constants. Find $\vec{E}$ and $\vec{B}$, and check that they satisfy Maxwell's equations in vacuum. What condition must you impose on ω and k?

9. Use the gauge function, $\lambda = -(1/4\pi\epsilon_0)(qt/r)$ to transform the potentials in **Q.13** and **Q.14**.

10. Unpolarised light is incident on an air dielectric interface. The interface is xy plane and plane of incidence is yz plane. The electric field of the reflected light is given by $\vec{E} = E_0\hat{x}\exp\left(\frac{ik}{2}\left(\sqrt{3}y+z\right)-i\omega t\right)$.
where k is the propagation constant in air and ω is the angular frequency of the light. Assume magnetic permeability $\mu = \mu_0$.
(a) Determine dielectric constant of the second medium
(b) Determine the direction of the poynting vector in the dielectric medium.

11. A polarised wave is incident from air to polystrene with $\mu = \mu_0$, $\varepsilon = 2.6\varepsilon_0$ at Brewster angle. Determine the transmission angle (θ_t).

12. A left circuarly polarised beam $\lambda_0 = 6000\,Å$ is incident normally on a calcite crystal. Calculate the thickness of the crystal so that emergent light is
(i) R.C.P. (ii) P. P.
Assume that $n_0 = 1.544$ and $n_e = 1.555$

13. An electromagnetic wave $E = 4\cos(\omega t - kz)\hat{x}$ incident from air to glass (n = 1.5) interface normally.
(i) Calculate the reflected and transmitted amplitude of electric field also their phases.
(ii) Calculate the percentage of energy reflected and transmitted at the interface.
(iii) Brewster angle for interface.

14. In the case of an oscillating electric dipole, $p(t) = p_0\cos(\omega t)$. Calculate the power radiated by the dipole.

15. A particle of charge q moves in a circle of radius R at a constant speed v. Calculate the power radiated by the charge particle.

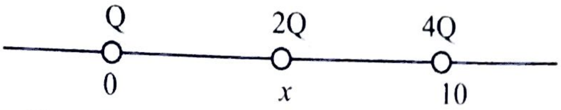
LEVEL-2

Solve Yourself

CAREER ENDEAVOUR
Best Institute for IIT-JAM, NET & GATE

CSIR-UGC-NET/JRF|GATE-PHYSICS
ELECTROMAGNETIC THEORY
Assignment-1 : COULOMB'S & GAUSS LAW

1. Three positively charged particles lie on a straight line at positions 0, x and 10 as indicated in the figure below. Their charges are Q, 2Q and 4Q cm respectively.



If the charges at x = 0 and x = 10 are fixed and the charge at x is movable, the system will be in equilibvrium when x =

(a) 8 (b) 2 (c) 20/3 (d) 10/3

2. Two point charges $Q_1 = 1$ nC and $Q_2 = 2$ nC are kept in free space such that the distance between them is 0.1 m. **[GATE 2001]**

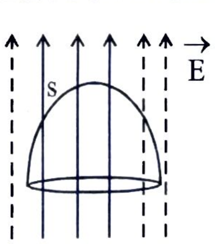
(a) The force on Q_2 is along the direction from Q_2 to Q_1
(b) The force on Q_2 is the same in magnitude as that on Q_1
(c) The force on Q_1 is attractive
(d) A point charge $Q_3 = -3$ nC, placed at the midpoint between Q_1 and Q_2, experiences no net force.

3. When a particle of charge q is at rest, it produces
(a) Only electric field (b) Only magnetic field
(c) Both electric and magnetic fields. (d) A magnetic field depending upon the sign of the charge.

4. The magnitude of the electrostatic field of an infinite straight wire carrying a line charge density λ at a distance Z from it is given by

(a) $E = \frac{1}{4\pi\varepsilon_0}.\frac{\lambda}{Z^2}$ (b) $E = \frac{1}{4\pi\varepsilon_0}.\frac{2\lambda}{Z^2}$ (c) $E = \frac{1}{4\pi\varepsilon_0}.\frac{2\lambda}{Z}$ (d) $E = \frac{1}{4\pi\varepsilon_0}.\frac{\lambda}{Z}$

5. A hemispherical surface of radius R is in a constant electric field $\vec{E}$ directed perpendicular to the base, as shown. The flux through the curved surface S of the hemisphere is



(a) 0 (b) $\pi R^2 E$ (c) $2\pi R^2 E$ (d) $4\pi R^2 E$

6. An electric field $\vec{E}(\vec{r}) = \frac{1}{r}\left(\alpha\hat{r} + \beta\sin\theta\cos\phi\hat{\phi}\right)$ exists in space. What will be the total charge enclosed in a sphere of unit radius centered at the origin?

(a) $4\pi\varepsilon_0\alpha$ (b) $4\pi\varepsilon_0(\alpha+\beta)$ (c) $4\pi\varepsilon_0(\alpha-\beta)$ (d) $4\pi\varepsilon_0\beta$

7. A solid sphere of radius R carries a uniform volume charge density ρ. The magnitude of electric field inside the sphere at a distance r from the centre is : **[GATE 2005]**

(a) $\frac{r\rho}{3\varepsilon_0}$ (b) $\frac{R\rho}{3\varepsilon_0}$ (c) $\frac{R^2\rho}{r\varepsilon_0}$ (d) $\frac{R^3\rho}{r^2\varepsilon_0}$

8. A shpere of radius R carrries a volume charge density $\rho = \rho_0 r$, where ρ_0 is a constant and r is the radial distance from the centre of the charged sphere. The intensity of the electric field is proportional to:

(a) r^2 for $r \le R$ and $1/r^2$ for $r \ge R$ (b) r for $r \le R$ and $1/r^2$ for $r \ge R$

(c) $1/r^2$ for both $r \le R$ and $r \ge R$ (d) $1/r$ for $r \le R$ and $1/r^2$ for $r \ge R$

9. The electric field due to a charge q is given by $\vec{E} = \frac{q}{r^2}\hat{r}$. The value of the surface integral $\oint_s \vec{E}.\vec{ds}$ depends only

(a) On the area of the surface (b) On the radial distance r.
(c) On the charge (d) On the shape of the surface

10. The electric fields of a long straight wire varies with distance r (perpendicular to the wire) as

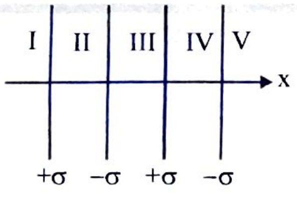
(a) $\frac{1}{r}$ (b) ln r (c) $1/r^2$ (d) $1/r^3$

11. If $\vec{V} = \hat{i} + \hat{j} + \hat{k}$, where $\hat{i}$, $\hat{j}$ and $\hat{k}$ are the unit vectors in three-dimensions, the value of $\vec{\nabla}.\vec{V}$ is :
(a) -3 (b) 2 (c) 0 (d) 3

12. Consider a uniformly charged sphere of radius, R. The charge per unit volume is ρ. The magnitude of the electric field at a distance of r from the centre of the sphere (r < R), is given by: (ε_0 is the permittivity of free space)

(a) $E = \frac{\rho r}{3\varepsilon_0}$ (b) $E = \frac{\rho r^2}{3\varepsilon_0}$ (c) $E = \frac{\rho R^3}{4\pi\varepsilon_0 r^2}$ (d) $E = \frac{\rho r}{4\pi\varepsilon_0}$

13. Four infinite conducting plates carry equal but opposite uniform charge densities $+\sigma$ as shown. The electrostatic fields in the regions I, II, III, IV and V are given respectively by



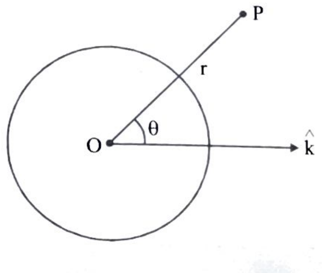
(a) $0, \frac{\sigma}{\varepsilon_0}\hat{x}, 0, \frac{\sigma}{\varepsilon_0}\hat{x}, 0$ (b) $\frac{\sigma}{\varepsilon_0}\hat{x}, 0, \frac{\sigma}{\varepsilon_0}\hat{x}, 0, \frac{\sigma}{\varepsilon_0}\hat{x}$

(c) $0, \frac{\sigma}{\varepsilon_0}\hat{x}, -\frac{\sigma}{\varepsilon_0}\hat{x}, \frac{\sigma}{\varepsilon_0}\hat{x}, 0$ (d) $0, +\frac{\sigma}{\varepsilon_0}\hat{x}, \frac{\sigma}{2\varepsilon_0}\hat{x}, +\frac{\sigma}{\varepsilon_0}\hat{x}, 0$

14. An electric field in a region is given by $\vec{E}(x, y, z) = ax\hat{i} + cz\hat{j} + 6by\hat{k}$. For which of a, b, c does this represent an electrostatic field ? **[JEST 2012]**
(a) 13, 1, 12 (b) 17, 6, 1 (c) 13, 1, 6 (d) 45, 6, 1

15. Consider an electric field $\vec{E}$ existing in the interface between a conductor and free space. Then the electric field $\vec{E}$ is : **[GATE 2001]**
(a) External to the conductor and normal to the conductor's surface
(b) Internal to the conductor and normal to the conductor's surface
(c) External to the conductor and tangential to the conductor's surface
(d) Both external and internal to the conductor and normal to the conductor's surface

16. A spherical conductor of radius a is placed in a uniform electric field $\vec{E} = E_0\hat{k}$. The potential at a point $P(r,\theta)$ for r > a, is given by, $\varphi(r,\theta) = \text{constant} - E_0 r\cos\theta + \frac{E_0 a^3}{r^2}\cos\theta$ **[GATE 2011]**
Where 'r' is the distance of P from the centre O of the sphere and θ is the angle OP makes with the z-axis.



The charge density on the sphere at $\theta = 30^\circ$ *is* :
(a) $3\sqrt{3}\,\varepsilon_0 E_0/2$ (b) $3\varepsilon_0 E_0/2$ (c) $\sqrt{3}\varepsilon_0 E_0/2$ (d) $\varepsilon_0 E_0/2$

17. If $\vec{E}_1 = xy\hat{i} + 2yz\hat{j} + 3xz\hat{k}$ and $\vec{E}_2 = y^2\hat{i} + (2xy + z^2)\hat{j} + 2yz\hat{k}$ then **[JEST 2013]**
(a) Both are impossible electrostatic fields. (b) Both are possible electrostatic fields.
(c) Only $\vec{E}_1$ is a possible electrostatic field. (d) Only $\vec{E}_2$ is a possible electrostatic field.

18. The charge per unit length of a circular wire of radius a in the xy-plane, with its center at the origin, is $\lambda = \lambda_0\cos\theta$, where λ_0 is a constant and the angle θ is measured from the positive x-axis. The electric field at the center of the circle is **[NET Dec. 2016]**
(a) $\vec{E} = -\frac{\lambda_0}{4\varepsilon_0 a}\hat{i}$ (b) $\vec{E} = \frac{\lambda_0}{4\varepsilon_0 a}\hat{i}$ (c) $\vec{E} = -\frac{\lambda_0}{4\varepsilon_0 a}\hat{j}$ (d) $\vec{E} = \frac{\lambda_0}{4\pi\varepsilon_0 a}\hat{k}$

19. Identical charge q are placed at five vertices of a regular hexagon of side a. The magnitude of the electric field and the electrostatic potential at the centre of the hexagon are respectively **[GATE 2017]**
(a) 0, 0 (b) $\frac{q}{4\pi\varepsilon_0 a^2}, \frac{q}{4\pi\varepsilon_0 a}$ (c) $\frac{q}{4\pi\varepsilon_0 a^2}, \frac{5q}{4\pi\varepsilon_0 a}$ (d) $\frac{\sqrt{5}q}{4\pi\varepsilon_0 a^2}, \frac{\sqrt{5}q}{4\pi\varepsilon_0 a}$

20. $\int_{-\infty}^{+\infty}(x^2+1)\,\delta(x^2-3x+2)\,dx = ?$ **[JEST 2017]**
(a) 1 (b) 2 (c) 5 (d) 7

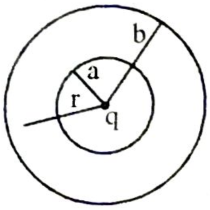
21. A sphere of inner radius 1 cm and outer radius 2 cm, centered at origins has a volume charge density $\rho_0 = \frac{K}{4\pi r}$, where K is a nonzero constant and r is the radial distance. A point charge of magnitude 10^{-3} C is placed at the origin. For what value of K in units of C/m^2, the electric field inside the shell is constant ? **[JEST 2017]**

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-2 : Electric Potential and Conductors

1. A conducting spherical shell of inner radius a and outer radius b has a point charge q located at the centre of the shell. The potential at a distance r from the centre $(a < r < b)$ is:



(a) 0 (b) $\frac{1}{4\pi\varepsilon_0}\frac{q}{a}$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{b}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

2. The field $\vec{F} = yz\hat{i} + zx\hat{j} + xy\hat{k}$ may represent

(a) Only magnetostatic field (b) Only an electrostatic field
(c) Both electrostatic and magnetostatic field (d) Neither electrostatic nor magnetostatic field.

3. Two point charges q and 4q are located at r_1 and r_2, respectively, on the xy-plane. The magnitude Q and location R of a third charge to be placed on the plane such that total force on the each of the three charges vanishes, are

(a) $Q = -4q/9$ and $R = (2r_1 + r_2)/3$ (b) $Q = -4q/5$ and $R = (r_1 + 2r_2)/3$

(c) $Q = -4q/25$ and $R = (16r_1 + r_2)/\sqrt{17}$ (d) $Q = -9q/4$ and $R = (r_1 + 2r_2)/3$

4. The amount of energy required to charge a metallic sphere of radius 2.0 m to a potential of 3000 V in air is:

(a) 1×10^{-3} Joule (b) 2×10^{-3} Joule (c) 3×10^{-3} Joule (d) 4×10^{-3} Joule

5. A small charged spherical shell of radius 0.01 m is at a potential of 30V. The electrostatic energy of the shell is

(a) 10^{-10} J (b) 5×10^{-10} J (c) 5×10^{-9} J (d) 10^{-9} J

6. Suppose that the electric field on the xy-plane is given by

$$\vec{E} = P\left[xy\hat{i} + \left(\frac{1}{2}x^2 + y^2\right)\hat{j}\right]$$

The magnitude of the difference in potential between the origin (0, 0) and the point (1, 2) is:

(a) $\frac{5}{4}P$ (b) $\frac{11}{3}P$ (c) $\frac{7}{2}P$

(d) Not unique, it depends on the path joining the two points.

7. If the electrostatic potential were given by $\phi = \phi_0\left(x^2 + y^2 + z^2\right)$, where ϕ_0 is constant, then the charge density giving rise to the above potential would be : **[GATE 2005]**

(a) 0 (b) $-6\,\phi_0\,\varepsilon_0$ (c) $-2\,\phi_0\,\varepsilon_0$ (d) $-\frac{6\phi_0}{\varepsilon_0}$

8. Equipotential surfaces corresponding to a particular charge distribution are given by $4x^2 + (y-2)^2 + z^2 = V_i$, where the values of V_i are constants. The electric field $\vec{E}$ at the origin is:

(a) $\vec{E} = 0$ (b) $\vec{E} = 2\hat{x}$ (c) $\vec{E} = 4\hat{y}$ (d) $\vec{E} = -4\hat{y}$

9. In a region of space that does not contain any electric charge, the electrostatic potential satisfies Laplace's equation. Suppose that the potential in such a situation is given by the formula

$$V(x, y, z) = A\left(bx^2 + \frac{1}{2}y^2 - z^2\right)$$

Where A and b are constants. Then the value of b

(a) Can be arbitrary (b) Must be zero (c) Must be 1/2 (d) Must be 1

10. The electrostatic potential in a given region of space is $\phi(\bar{r}) = \frac{1}{\epsilon_0}\left[x^2 + y^2 - 2z^2\right]$. The charge density $\rho(\bar{r})$ in the region is

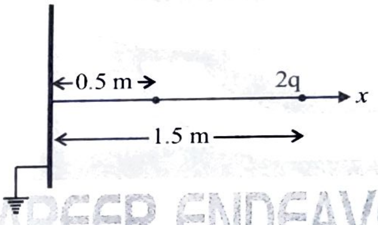
(a) $\frac{-x-y+4z}{r^3}$ (b) $\frac{x+y-2z}{r}$ (c) zero (d) $\frac{4}{r^2}$

11. Which one of the following is not correct?

(a) $\nabla \cdot (\nabla\phi) = \nabla^2\phi$ (b) $\nabla \times (\nabla \times A) = \nabla(\nabla \cdot A) - \nabla^2 A$

(c) $\nabla \cdot (\nabla \times A) = 0$ (d) $\nabla \times (\nabla\phi) = \phi$

12. Two charges q and 2q are placed along the x-axis in front of a grounded, infinite conducting plane, as shown in the figure. They are located respectively at a distance of 0.5 m and 1.5 m from the plane. The force acting on the charge q is: **[GATE 2010]**



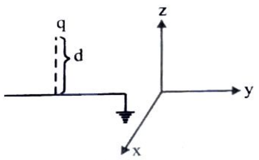
(a) $\frac{1}{4\pi\varepsilon_0}\frac{7q^2}{2}$ (b) $\frac{1}{4\pi\varepsilon_0}2q^2$ (c) $\frac{1}{4\pi\varepsilon_0}q^2$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{2}$

13. For a scalar function φ satisfying the Laplace equation, $\nabla\varphi$ has **[GATE 2013]**

(a) zero curl and non-zero divergence (b) non-zero curl and zero divergence

(c) zero curl and zero divergence (d) non-zero curl and non-zero divergence

14. Let a point charge +q be at a distance d from an infinite conducting plate which is grounded.



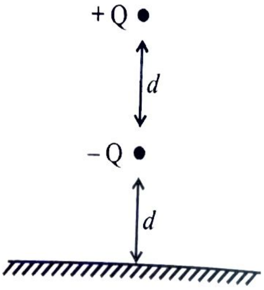
The force experienced by the charge is given by

(a) $\vec{F} = +\frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}\hat{k}$ (b) $\vec{F} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}\hat{k}$ (c) $\vec{F} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{(2d)^2}\hat{k}$ (d) $\vec{F} = +\frac{1}{4\pi\varepsilon_0}\frac{q^2}{(2d)^2}\hat{k}$

15. A point charge is placed between two semi-infinite conducting plates which are inclined at an angle of 30° with respect to each other. The number of image charges is_______ **[GATE 2015]**

16. A point charge +q is placed outside a grounded conducting sphere of radius a. Which of the following statements is not true?
(a) there is an attractive force between the sphere and the point charge
(b) the induced surface charge density on the sphere is not the same everywhere
(c) the electric field inside the sphere is zero
(d) the total induced charge on the sphere is -q

17. Two points charges +Q and –Q are placed away from a grounded conducting plane as shown in the figure. The net force on the charge –Q is



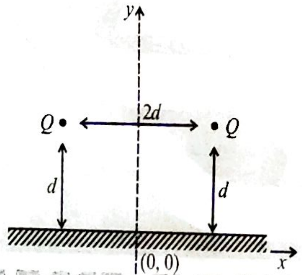
(a) $\dfrac{Q^2}{4\pi\in_0 d^2}$ away from the conducting plane

(b) $\dfrac{Q^2}{4\pi\in_0 d^2}\left(\dfrac{137}{144}\right)$ towards the conducting plane

(c) $\dfrac{Q^2}{4\pi\in_0 d^2}\left(\dfrac{31}{36}\right)$ away from the conducting plane

(d) $\dfrac{Q^2}{4\pi\in_0 d^2}\left(\dfrac{137}{144}\right)$ away from the conducting plane

18. Two positive point charges Q are placed as shown in the figure a distance d away from a grounded conducting plane. The distance between the point charges is $2d$. The net force on the point charges located at the point (d, d) is



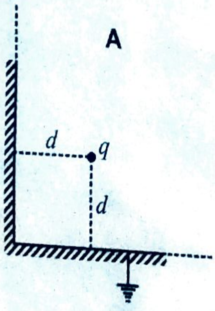
(a) $\dfrac{Q^2}{4\pi\in_0(4d^2)}\hat{i}$

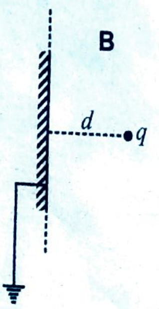
(b) $\dfrac{Q^2}{4\pi\in_0(4d^2)}\left(\dfrac{2\sqrt{2}-1}{2\sqrt{2}}\hat{i}-\dfrac{2\sqrt{2}+1}{2\sqrt{2}}\hat{j}\right)$

(c) $\dfrac{Q^2}{4\pi\in_0(4d^2)}\left(\dfrac{1}{2}\hat{i}-\dfrac{3}{2}\hat{j}\right)$

(d) $\dfrac{Q^2}{4\pi\in_0(4d^2)}\left(\dfrac{\sqrt{2}+1}{\sqrt{2}}\hat{i}-\dfrac{\sqrt{2}-1}{\sqrt{2}}\hat{j}\right)$

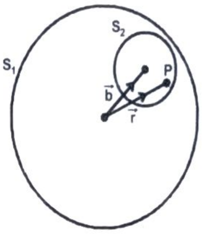
19. Consider the following situations.





In situation A, two semi-infinite earthed conducting planes meet at right-angles. A point charge q, is placed at a distance d from each plane, as shown in the figure A. The magnitude of the force exerted on the charge q is denoted F_A.
In situation B, the same charge q is kept at the same distance d from an infinite earthed conducting plane, as shown in the figure B. The magnitude of the force exerted on the charge q is denoted F_B.
Find the numerical ratio F_A/F_B. **[TIFR 2017]**

20. Consider a sphere S_1 of radius R which carries a uniform charge of density ρ. A smaller sphere S_2 of radius $a < \frac{R}{2}$ is cut out and removed from it. The centers of the two spheres are separated by the vector $\vec{b} = \hat{n}\frac{R}{2}$, as shown in the figure. **[NET June 2016]**



The electric field at a point P inside S_2 is

(a) $\frac{\rho R}{3\varepsilon_0}\hat{n}$ (b) $\frac{\rho R}{3\varepsilon_0 a}(\vec{r} - \hat{n}a)$ (c) $\frac{\rho R}{6\varepsilon_0}\hat{n}$ (d) $\frac{\rho a}{3\varepsilon_0 R}\vec{r}$

21. Which of the following force fields is/are conservative ?

I. $(4x^3y + 3x^2z^2)\mathbf{i} + (x^4 + 3y^2z^2)\mathbf{j} + 2z(x^3 + y^3)\mathbf{k}$

II. $(yz^4 + x^5)\mathbf{i} + (x^4z + x^2y^3)\mathbf{j} + (x^4y + z^5)\mathbf{k}$

III. $x(3xy^2 + 4z^2)\mathbf{i} + (z^4 + 2x^3y)\mathbf{j} + 2z^2(2yz + 3x^2)\mathbf{k}$

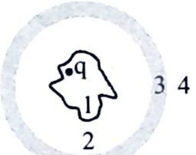
(a) II and III only (b) I, II and III (c) I and III only
(d) I and II only (e) I only

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-3 : Dielectric Polarization

1. An arbitrarily shaped conductor encloses a charge q and is surrounded by a conducting hollow sphere as shown in the figure. Four different regions of space, 1, 2, 3 and 4, are indicated in the figure. Which one of the following statements is correct?



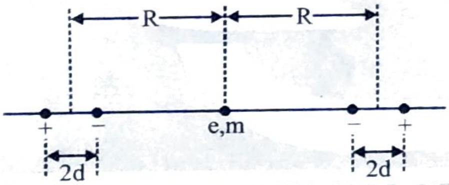
(a) The electric field lines in region 2 are not affected by the position of the charge q

(b) The surface charge density on the inner wall of the hollow sphere is uniform

(c) The surface charge density on the outer surface of the sphere is always uniform irrespective of the position of charge q in region 1

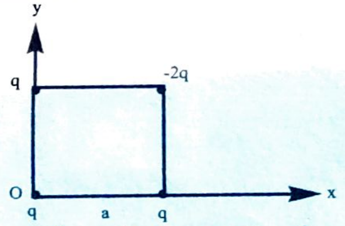
(d) The electric field in region 2 has a radial symmetry

2. A particle of charge e and mass m is located at the midpoint of the line joining two mixed collinear dipoles with unit charges as shown in the figure. (The particle is constrained to move only along the line joining the dipoles). Assuming that the length of the dipoles is much shorter than their separation, the natural frequency of oscillation of the particle is **[NET June 2013]**



(a) $\sqrt{\dfrac{6e^2R^2}{\pi\varepsilon_0 md^5}}$ (b) $\sqrt{\dfrac{6e^2R}{\pi\varepsilon_0 md^4}}$ (c) $\sqrt{\dfrac{6e^2d^2}{\pi\varepsilon_0 mR^5}}$ [✓ (d)] $\sqrt{\dfrac{6e^2d}{\pi\varepsilon_0 mR^4}}$

3. Four charges are placed at the four corners of a square of side a as shown in the figure. The electric dipole moment of this configuration is : **[GATE 2002]**

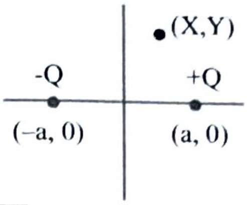


(a) $\vec{p} = qa\hat{i} + qa\hat{j}$ (b) $\vec{p} = -qa\hat{i} + qa\hat{j}$ (c) $\vec{p} = -qa\hat{i} - qa\hat{j}$ (d) $\vec{p} = qa\hat{i} - qa\hat{j}$

4. Three point charges q, q and $-2q$ are located at $(0, -a, a)$, $(0, a, a)$ and $(0, 0, -a)$, respectively. The net dipole moment of this charge distribution is : **[GATE 2006]**

(a) $4qa\hat{k}$ (b) $2qa\hat{k}$ (c) $-4qa\hat{i}$ (d) $-2qa\hat{j}$

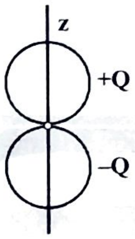
5. Consider two charges +Q and −Q placed at the points (a, 0) and (−a, 0) in a plane, as shown in the figure on the right. If the origin is moved to the point (X, Y), the magnitude of the dipole moment of the given charge distribution with respect to this origin will be **[TIFR 2013]**



(a) $Q\sqrt{(a-X)^2+y^2}-Q\sqrt{(a+X)^2+y^2}$ (b) $Q(a-X)-Q(-a+X)$

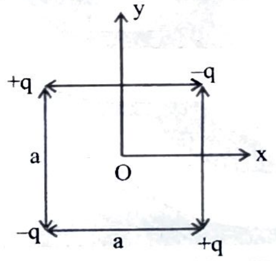
(c) 2Qa (d) $2Q\sqrt{X^2+Y^2}$

6. An electric dipole is constructed by fixing two circular charged rings, each of radius 'a', with an insulating contact (see figure). One of these rings has total charge +Q and the other has total charge −Q. If the charge is distributed uniformly along each ring, the dipole moment about the point of contact will be **[TIFR 2014]**



(a) $\frac{Qa}{\pi}\hat{z}$ (b) $4\pi Qa\hat{z}$ (c) $2Qa\,\hat{z}$ (d) Zero

7. The dipole moment of the following configuration about the centre:

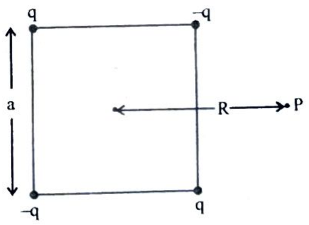


(a) $4\,qa\left(\hat{i}+\hat{j}\right)$ (b) $2\,qa\left(\hat{i}-\hat{j}\right)$ (c) 0 (d) $8\,qa^2\,\hat{k}$

8. An electric point charge +q is placed at the point (1, 1) of the xy-plane in which two grounded semi-infinite conducting plates along the positive x and y-axes meet see figure). The electric potential in the positive quadrant at a large distance r goes as **[NET 2008]**

(a) $V(r)\sim r^{-1}$ (b) $V(r)\sim r^{-2}$ (c) $V(r)\sim r^{-3}$ (d) $V(r)\sim r^{-4}$

9. Four charges (two +q and two −q) are kept fixed at the four vertices of a square of side 'a' as shown



At the point P which is at a distance R from the centre (R >> a), the potential is proportional to

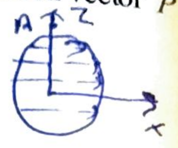
(a) $\frac{1}{R}$ (b) $\frac{1}{R^2}$ (c) $\frac{1}{R^3}$ (d) $\frac{1}{R^4}$ **[NET Dec. 2012]**

10. Consider a spherical dielectric material of radius 'a', centered at origin. If the polarization vector $\vec{P} = P_0\hat{e}_x$, where P_0 is a constant of appropriate dimensions, then

($\hat{e}_x$, $\hat{e}_y$, and $\hat{e}_z$ are unit vectors in Cartesian - coordinate system)

$\vec{P} = P_0\hat{i}$ = Const.

$\rho_b = -\vec{\nabla}\cdot\vec{P}$
$= 0$

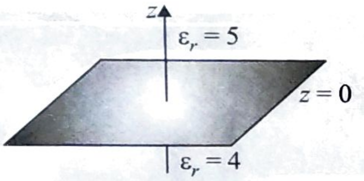


Correct (a) the bound volume charge density is zero
(b) the bound surface charge density is zero at (0, 0, a)
(c) the electric field is zero inside the dielectric
(d) the sign of the surface charge density changes over the surface.

11. A dielectric sphere of radius R carries a polarization $\vec{P} = k\vec{r}$ throughout its volume. The volume charge density Pb of the bound charges is **[NET June 2009]**

(a) –3k (b) 3k (c) –k (d) k

12. 4.4 Assume that z = 0 plane is th interface between two linear and homogeneous dielectrics (see figure). The relative permitivities are $\varepsilon_r = 5$ for $z > 0$ and $\varepsilon_r = 4$ for $z < 0$. The electric field in the region $z > 0$ is $\vec{E}_1 = (3\hat{i} - 5\hat{j} + 4\hat{k})\, kV/m$. If there are no free charges on the interface, the electric field in the region $z < 0$ is given by



(a) $\vec{E}_2 = \left(\frac{3}{4}\hat{i} - \frac{5}{4}\hat{j} + \hat{k}\right) kV/m$ (b) $\vec{E}_2 = (3\hat{i} - 5\hat{j} + \hat{k})\, kV/m$

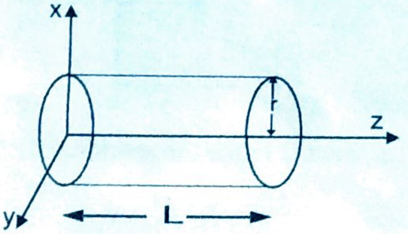
(c) $\vec{E}_2 = (3\hat{i} - 5\hat{j} - 5\hat{k})\, kV/m$ (d) $\vec{E}_2 = (3\hat{i} - 5\hat{j} + 5\hat{k})\, kV/m$

13. A unit cube made of dielectric material has a polarization $\vec{P} = 3\hat{i} + 4\hat{j}$ units. The edges of the cube are parallel to the Cartesian axes. Which of the following statements are true?
(a) the cube carries a volume bound charge of magnitude 5 units.
(b) there is a charge of magnitude 3 units on both the surfaces parallel to the y-z plane
(c) there is a charge of magnitude 4 units on both the surfaces parallel to the x-z plane.
(d) there is a net non-zero induced charge on the cube

14. A long, solid dielectric cylinder of radius 'a' is permanently polarized so that the polarization is everywhere radially outward, with a magnitude proportional to the distance from the axis of the cylinder, i.e., $\vec{p} = \frac{1}{2}P_0 r\hat{r}$. The bound charge density in the cylinder is given by

(a) $-P_0$ (b) P_0 (c) $-P_0/2$ (d) $P_0/2$

15. A cylindrical rod of length L and radius r, made of an inhomogeneous dielectric, is placed with its axis along the z direction with one end at the origin as shown below : **[GATE 2009]**



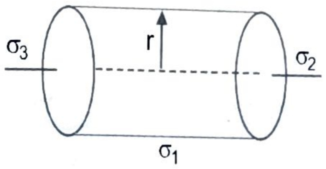
If the rod carries a polarization, $\vec{P} = \left(5z^2 + 7\right)\hat{k}$, the volume bound charge inside the dielectric is :

(a) Zero (b) $10\pi r^2 L$ (c) $-5\pi r^2 L$ (d) $-5\pi r^2 L^2$

16. A charge q is placed at the centre of an otherwise neutral dielectric sphere of radius a and relative permittivity $\in_r$. We denote the expression $q/4\pi \in_0 r^2$ by $E(r)$. Which of the following statements is false?

(a) The electric field inside the sphere, $r < a$, is given by $E(r)/\in_r$. **[JEST 2013]**
(b) The field outside the sphere, $r > a$, is given by $E(r)$.
(c) The total charge inside a sphere of radius $r > a$ is given by q.
(d) The total charge inside a sphere of radius $r < a$ is given by q.

17. A cylinder of radius R and length L carries a polarization $P = P_0\vec{r}$, where P_0 is a constant and $\vec{r}$ is a radial vector from the axis. The surface bound charges on the cylindrical surface (σ_1) and at the circular surfaces $(\sigma_2$ and $\sigma_3)$ as shown in the firgure are :



(a) $\sigma_1 = 0, \sigma_2 = \sigma_3 = P_0R$ (b) (b) $\sigma_1 = P_0R, \sigma_2 = \sigma_3 = 0$

(c) $\sigma_1 = P_0R^2/L, \sigma_2 = \sigma_3 = P_0R$ (d) $\sigma_1 = P_0R, \sigma_2 = \sigma_3 = P_0R^2/L$

18. A spherical shell of inner and outer radii a and b, respectively, is made of a dielectric material with frozen polarization $\vec{P}(r) = \frac{k}{r}\hat{r}$, where k is a constant and r is the distance from the its centre. The electric field in the region $a < r < b$ is, **[JEST 2015]**

(a) $\vec{E} = \frac{k}{\varepsilon_0 r}\hat{r}$ (b) $\vec{E} = -\frac{k}{\varepsilon_0 r}\hat{r}$ (c) $\vec{E} = 0$ (d) $\vec{E} = \frac{k}{\varepsilon_0 r^2}\hat{r}$

19. The relation $\vec{D} = \varepsilon_0\vec{E} + \vec{P}$ where, $\vec{D} \rightarrow$ dielectric constant; $\vec{E} \rightarrow$ electric field intensity; $\vec{P} \rightarrow$ polarization vector is applicable

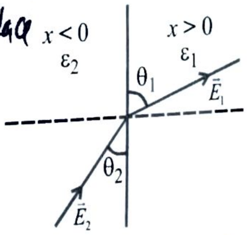
(a) For all medium (b) For dielectric medium
(c) Free space (d) Magnetic medium

20. The half space regions $x > 0$ and $x < 0$ are filled with dielectric media of dielectric constants ε_1 and ε_2 respectively. There is a uniform electric field in each part. In the right half, the electric field makes an angle θ_1 to the interface. The corresponding angle θ_2 in the left half satisfies **[NET June 2016]**

$\frac{\cot\theta_1}{\varepsilon_1} = \frac{\cot\theta_2}{\varepsilon_2}$ angle is with interface

$\frac{1}{\varepsilon_1\tan\theta_1} = \frac{1}{\varepsilon_2\tan\theta_2}$

$\varepsilon_1\tan\theta_1 = \varepsilon_2\tan\theta_2$



ε_2 ¦ ε_1 Interface

ε_2 | ε_1 Normal

(a) $\varepsilon_1 \sin\theta_2 = \varepsilon_2 \sin\theta_1$ (b) $\varepsilon_1 \tan\theta_2 = \varepsilon_2 \tan\theta_1$

(c) $\varepsilon_1 \tan\theta_1 = \varepsilon_2 \tan\theta_2$ (d) $\varepsilon_1 \sin\theta_1 = \varepsilon_2 \sin\theta_2$

21. An electric dipole $\vec{p}$ located in a uniform electric field with its direction along the electric field $\vec{E}$. The work required to rotate the dipole through 180° is:

(a) 2pE (b) pE (c) $\vec{p} \times \vec{E}$ (d) $2(\vec{p} \times \vec{E})$

22. Suppose the yz-plane forms a chargeless boundary between two media of permittivities e_{left} and e_{right} where $e_{\text{left}} : e_{\text{right}} = 1:2$. If the uniform electric field on the left is $\vec{E}_{\text{left}} = c(\hat{i} + \hat{j} + \hat{k})$ (where c is a constant), then the electric field on the right $\vec{E}_{\text{right}}$ is **[NET June 2015]**

(a) $c(2\hat{i} + \hat{j} + \hat{k})$ (b) $c(\hat{i} + 2\hat{j} + 2\hat{k})$ (c) $c\left(\frac{1}{2}\hat{i} + \hat{j} + \hat{k}\right)$ (d) $c\left(\hat{i} + \frac{1}{2}\hat{j} + \frac{1}{2}\hat{k}\right)$

23. Consider a parallel plate capacitor connected to an AC voltage source (as shown in fig.1). A conducting slab is introduced in the space between the plates from above (as shown in fig.2) **[NET 2008]**

$c' = \frac{A\varepsilon_0}{d - t\left(1 - \frac{1}{\varepsilon_r}\right)}$

$c' = \frac{A\varepsilon_0}{d-t}$

$(c' > c)$ ⓑ

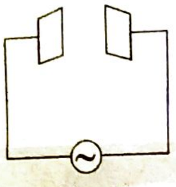


Fig. 1

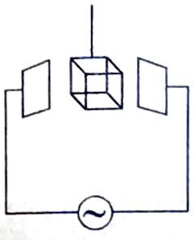
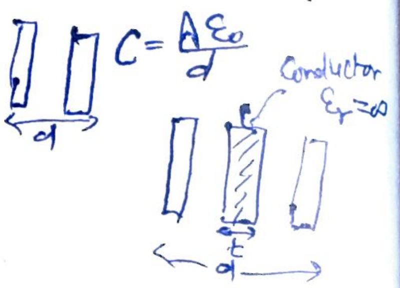


Fig. 2



$C = \frac{A\varepsilon_0}{d}$

The capacitance of the parallel plate capacitor.

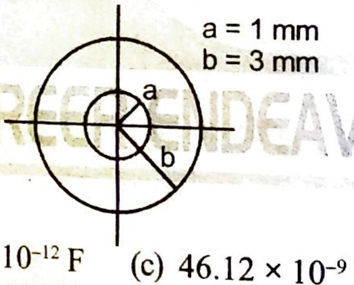
(a) Goes to zero. ~~(b)~~ Increases to a finite value.

(c) Decreases to a non-zero value. (d) Becomes infinite.

~~24.~~ A coaxial cable of uniform cross-section contains an insulating material of dielectric constant 3.5. The radius of the central wire is 0.01 m and that of the sheath is 0.02 m. The capacitance per kilometer of a cable is :

(a) 280.5 nF (b) 28.05 nF (c) 56.10nF (d) 2.805 nF **[GATE 2001]**

~~25.~~ A coaxial transmission line of length 1 m made with a cylindrical inner metallic core of radius 1 mm and a thin cylindrical outer conductor of radius 3 mm. The cross-section of the transmission line (not to scale) is shown in the figure below. The capacitance of this transmission line is nearest to



(a) 50.55×10^{-12} F (b) 75.16×10^{-12} F (c) 46.12×10^{-9} F

(d) 58.20×10^{-10} F (e) 36.15×10^{-11} F

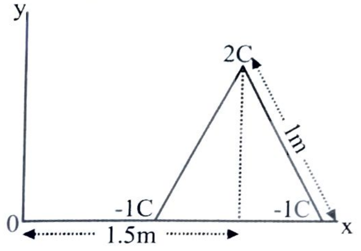
~~26.~~ A parallel plate capacitor with square plates of side 1 m separated by 1 micro meter is filled with a medium of dielectric constant of 10. If the charges on the two plates are 1 C and -1 C, the voltage across the capacitor is ______ kV. (up to two decimal places). ($\varepsilon_0 = 8.854 \times 10^{-12}$ F/m) **[GATE 2017]**

~~27.~~ A charged capacitor is made of two concentric cylinders of radii r_1 and r_2. The region between the cylindrical plates is filled with a medium of dielectric constant, k. The displacement vector $(\vec{D})$ at a distance $r(r_1 < r < r_2)$.

(a) Is independent of r. (b) Varies as ln r.

(c) Is proportional to r. (d) Varies as 1/r.

28. Three charges (2 C, –1 C, –1 C) are placed at the vertices of an equilateral triangle of side 1m as shown in the figure. The component of the electric dipole moment about the marked origin along the $\hat{y}$ direction is ____ cm.



[GATE 2017]

29. Two equal positive charges of magnitude $+q$ separated by a distance d are surrounded by a uniformly charged thin spherical shell of radius $2d$ bearing a total charge $-2q$ and centred at the midpoint between the two positive charges. The net electric field at distance r from the midpoint ($\gg d$) is **[JEST 2017]**

(a) zero
(b) proportional to d
(c) proportional to $1/r^3$
(d) proportional to $1/r^4$

30. For a point dipole of dipole moment $\vec{p} = p\hat{z}$ located at the origin, which of the following is (are) ***correct***?

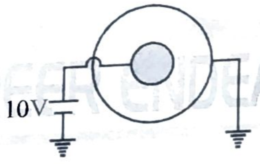
(a) The electric field at $(0, b, 0)$ is zero

(b) The work done in moving a charge q from $(0, b, 0)$ to $(0, 0, b)$ is $\dfrac{qp}{4\pi \in_0 b^2}$

(c) The electrostatic potential at $(b, 0, 0)$ is zero

(d) If a charge q is kept at $(0, 0, b)$ it will exert a force of magnitude $\dfrac{qp}{4\pi \in_0 b^2}$ on the dipole

31. In a coaxial cable, the radius of the inner conductor is 2 mm and that of the outer one is 5 mm. The inner conductor is at a potential of 10V, while the outer conductor is grounded. The value of the potential at a distance of 3.5 mm from the axis is ________________
(Specify your answer in volts to two digits after the decimal point)



CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-4 : Magnetostatics

1. The value of the magnetic field required to maintain non-relativistic protons of energy 1 MeV in a circular orbit of radius 100 mm is ________ Tesla. **[GATE 2014]**

   (Given: $m_p = 1.67\times10^{-27}\,kg,\ e = 1.6\times10^{-19}\,C$

2. An electron with kinetic energy of 10 keV is moving in a circular in a plane perpendicular to a uniform magnetic field of strength 1 tesla $(=1\times10^4$ gauss$)$. The period of rotation is nearest to

   (a) 2.8×10^{-12}s (b) 5.6×10^{-12}s (c) 1.8×10^{-11}s (d) 1.1×10^{-10}s

3. A magnetic field $\vec{B} = B_0\left(\hat{i}+2\hat{j}-4\hat{k}\right)$ exists at a point. If a test charge moving with a velocity $\vec{\upsilon} = \upsilon_0\left(3\hat{i}-\hat{j}+2\hat{k}\right)$ experiences no force at a certain point. The electric field at that point in SI units is

   (a) $\vec{E} = -\upsilon_0 B_0\left(3\hat{i}-2\hat{j}-4\hat{k}\right)$ (b) $\vec{E} = -\upsilon_0 B_0\left(\hat{i}+\hat{j}+7\hat{k}\right)$ **[JEST 2012]**

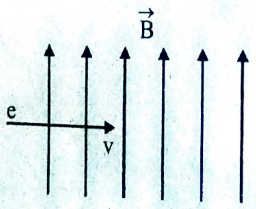
   (c) $\vec{E} = \upsilon_0 B_0\left(14\hat{j}+7\hat{k}\right)$ (d) $\vec{E} = -\upsilon_0 B_0\left(14\hat{j}+7\hat{k}\right)$

4. The x- and z-components of a static magnetic field in a region are $B_x = B_0(x^2-y^2)$ and $B_z = 0$, respectively. Which of the following solutions for its y-component is consistent with the Maxwell equations ?

   (a) $B_y = B_0 xy$ (b) $B_y = -2B_0 xy$ **[NET June 2016]**

   (c) $B_y = -B_0(x^2-y^2)$ (d) $B_y = B_0\left(\frac{1}{3}x^3 - xy^2\right)$

5. A stream of electrons eneters, from left to right, a uniform magnetic field (B) which is pointing upwards as shown in the figure. The field deflects the stream of electrons.



   (a) Downward (in the plane of the paper) (b) Upward (in the plane of the paper)
   (c) Into the paper (d) Out of the Paper.

6. A charged particle moving with a constant velocity enters a magnetic field perpendicular to its velocity. In which direction y an electric field should be applied to compensate the magnetic force?
   (a) Along the initial velocity
   (b) Perpendicular to the initial velocity and parallel to the magnetic field.
   (c) Perpendicular to both, the initial velocity and the magnetic field.
   (d) Along the magnetic field.

A charge q moves in a combined electric field $\vec{E}$ and magnetic induction $\vec{B}$. Then, as the charge moves

(a) Both the electric field and magnetic induction do work on it.

(b) The electric field does work but magnetic induction does no work on it.

(c) Magnetic induction does work but electric field does no work on it.

(d) Both electric field and magnetic induction do no work on it.

When a charged particle with kinetic energy E enters a region of uniform magnetic field $\vec{B}$ directed perpendicular to its velocity, it is found to move in circle of radius R. If the particle had kinetic energy 2E, the radius of the path would have been

(a) $R/\sqrt{2}$ (b) $\sqrt{2}R$ (c) $R/2$ (d) $2R$

An alpha particle is accelerated in a cyclotron. It leaves the cyclotron with a kinetic energy of 16 MeV. The potential difference between the D electrodes is 50 kilovolts. The number of revolutions the alpha particle makes in its spiral path before it leaves the cyclotron is _______ **[GATE 2016]**

10. The force between two long and parallel wires carrying currents I_1 and I_2 and separated by a distance D is proportional to **[NET Dec. 2013]**

(a) I_1I_2 / D (b) $(I_1 + I_2) / D$ (c) $(I_1 I_2 / D)^2$ (d) $I_1 I_2 / D^2$

11. An infinite conducting sheet in the x-y plane carries a surface current density K along the y-axis. The magnetic field B for z > 0 is : **[GATE 2003]**

(a) $B = 0$ (b) $B = \mu_0 K\hat{k}/z$ (c) $B = \mu_0 K\hat{i}/2$ (d) $B = \mu_0 K\hat{j}/\left(x^2+z^2\right)^{0.5}$

12. The x and y plane carries a uniform surface current of density $\vec{K} = 50\,\hat{i}$ A/m. The magnetic field at the point z = –0.5 m is : **[GATE 2001]**

(a) 10×10^{-6} Wb (b) 1×10^{-6} Wb (c) $\pi\times10^{-6}$ Wb (d) $10\pi\times10^{-6}$ Wb/m^2

13. A uniform surface current is flowing in the positive y-direction over an infinite sheet lying in x-y plane. The direction of the magnetic field is: **[GATE 2011]**

$\vec{B} = \frac{\mu_0}{2}\hat{K}\times\hat{n}$

$\hat{B} = \hat{I}\times\hat{n}$

$z>0$

$\hat{B} = \hat{J}\times\hat{K} = \hat{i}$

$\therefore z<0 \quad \hat{B} = -\hat{i}$

(a) Along $\hat{i}$ for z > 0 and along $-\hat{i}$ for z < 0. (b) Along $\hat{k}$ for z > 0 and along $-\hat{k}$ for z < 0

(c) Along $-\hat{i}$ for z > 0 and along $\hat{i}$ for z < 0 (d) Along $-\hat{k}$ for z > 0 and along $\hat{k}$ for z < 0

14. Three infinitely long wires are placed equally apart on the circumference of a circle of radius a, perpendicular to its plane. Two of the wires carry current I each, in the same direction, while the third carries current 2I along the direction opposite to the other two. The magnitude of the magnetic induction $\vec{B}$ at a distance r from the centre of the circle, for r > a, is :

(a) 0 (b) $\frac{2\mu_0}{\pi}\frac{I}{r}$ (c) $-\frac{2\mu_0}{\pi}\frac{I}{r}$ (d) $\frac{2\mu_0}{\pi}\frac{Ia}{r^2}$

15. Electric current of uniform current density is flowing through an infinitely long wire with a circular cross-section of constant radius R. Which of the following relations gives the magnitude B of the magnetic field measured inside the wire at a distance r from the central axis of the wire (so that r < R)?

(a) $B\propto r$ (b) $B\propto \ln r$ (c) $B\propto 1/r$ (d) $B\propto 1/r^2$

16. A wire of circular cross section of radius R carries a volume current density $\overline{J} = kr^2\hat{z}$ along the length of the wire. The magnetic field at a position r < R is :

(a) $\frac{\mu_0}{2}kr^3\hat{z}$ (b) $\frac{\mu_0}{4}k\,r^3\hat{\phi}$ (c) $\frac{\mu_0}{4\pi}k\,r^3\hat{r}$ (d) $\frac{\mu_0}{4\pi}k\,r^2\hat{\phi}$

17. Three infinitely long parallel wires separated by a distance d from each other, carrying current I each are kept in the same plane. The magnetic field is found to be zero at a distance x on both sides of the central wire. The values of x are :

(a) $\pm d/2$ (b) $\pm d/\sqrt{2}$ (c) $\pm d/\sqrt{3}$ (d) $\pm d/3$

18. An electron moves with velocity $\hat{v} = \hat{j}.v_0$ under the combined influence of $\vec{E} = \hat{i}E_0$ and $\vec{B} = -\hat{k}B_0$ fields. The force on the electron is in the

(a) Y direction (b) Z direction (c) YZ plane (d) X direction

19. The strength of magnetic field at the center of a regular hexagon with sides of length a carrying a steady current I is : **[JEST 2016]**

(a) $\frac{\mu_0 I}{\sqrt{3}\pi a}$ (b) $\frac{\sqrt{6}\mu_0 I}{\pi a}$ (c) $\frac{3\mu_0 I}{\pi a}$ (d) $\frac{\sqrt{3}\mu_0 I}{\pi a}$

CSIR-UGC-NET/JRF | GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-5 : Vector Potential and Magnetisation

1. Which one of the following current densities, $\vec{J}$, can generate the magnetic vector potential $\vec{A} = \left(y^2\hat{i} + x^2\hat{j}\right)$? **[GATE 2009]**

(a) $\frac{2}{\mu_0}\left(x\hat{i}+y\hat{j}\right)$ (b) $-\frac{2}{\mu_0}\left(\hat{i}+\hat{j}\right)$ (c) $\frac{2}{\mu_0}\left(\hat{i}-\hat{j}\right)$ (d) $\frac{2}{\mu_0}\left(x\hat{i}-y\hat{j}\right)$

2. The vector potential in a region is given as $\vec{A}(x,y,z) = -y\hat{i}+2x\hat{j}$. The associated magnetic induction $\vec{B}$ is

(a) $\hat{i}+\hat{k}$ (b) $3\hat{k}$ (c) $-\hat{i}+2\hat{j}$ (d) $-\hat{i}+\hat{j}+\hat{k}$ **[GATE 2006]**

3. If the vector potential **[GATE 2014]**

$$\vec{A} = \alpha x\hat{x} + 2y\hat{y} - 3z\hat{z}$$

satisfies the Coulomb gauge, the value of the constant α is ____________

4. Consider an infinite plane at $z=0$ with uniform surface current density $\vec{K} = K\hat{i}$. The direction of the magnetic field $\vec{B}$ and the vector potential $\vec{A}$ of this current distribution at a distance d along the positive z-axis are :

(a) $\vec{B}$ along $\hat{j}$ and $\vec{A}$ along $\hat{k}$

(b) $\vec{B}$ along $\hat{k}$ and $\vec{A}$ along $\hat{j}$

(c) $\vec{B}$ along $-\hat{j}$ and $\vec{A}$ along $\hat{i}$

(d) $\vec{B}$ along $\hat{i}$ and $\vec{A}$ along $-\hat{j}$

5. Consider the magnetic field $\vec{B} = \alpha_0\left(\hat{i}y+\hat{j}x\right)$ and two vector potentials $\vec{A}_1 = \alpha_0\left(\hat{i}xz-\hat{j}yz\right)$ and $\vec{A}_2 = -\hat{k}\left(x^2-y^2\right)\alpha_0$, where α_0 is a constant and $\hat{i},\hat{j},\hat{k}$ represent the unit vectors along the cartesian axes. Identify the correct statement.

(a) Only $\vec{A}_1$ produces the magnetic field $\vec{B}$ but not $\vec{A}_2$

(b) Only $\vec{A}_2$ produces the magnetic field $\vec{B}$ but not $\vec{A}_1$

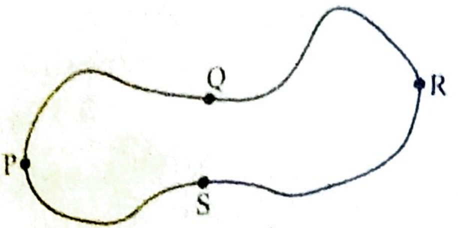
(c) Neither $\vec{A}_1$ nor $\vec{A}_2$ produces the magnetic field $\vec{B}$

(d) Both $\vec{A}_1$ and $\vec{A}_2$ produce the magnetic field $\vec{B}$.

6. There is a uniform magnetic field B in the z-direction in a certain region of space. The corresponding vector potential is given by.

(a) $\vec{A} = Bx\,\vec{j}$ (b) $\vec{A} = \frac{B\vec{r}}{r^2}$ (c) $\vec{A} = B\vec{r}$ (d) $\vec{A} = B\left(x\vec{i}+y\vec{k}\right)$

7. Given that magnetic flux through the closed loop PQRSP is ϕ. If $\int_{P}^{R} \vec{A}\cdot d\vec{l} = \phi_1$ along PQR, the value of $\int_{P}^{R} \vec{A}\cdot d\vec{l}$ along PSR is **[GATE 2015]**



(a) $\phi - \phi_1$ (b) $\phi_1 - \phi$ (c) $-\phi_1$ (d) ϕ_1

8. Given a uniform magnetic field $B = B_0\hat{k}$ (where B_0 is a constant), a possible choice for the magnetic vector potential A is **[NET Dec. 2015]**

(a) $B_0 y\hat{i}$ (b) $-B_0 y\hat{i}$ (c) $B_0(x\hat{j} + y\hat{i})$ (d) $B_0(x\hat{i} - y\hat{j})$

9. Which of the following magnetic vector potentials gives rise to a uniform magnetic field $B_0\hat{k}$? **[GATE 2016]**

(a) $B_0 z\hat{k}$ (b) $-B_0 x\hat{j}$

(c) $\frac{B_0}{2}(-y\hat{i} + x\hat{j})$ (d) $\frac{B_0}{2}(y\hat{i} + x\hat{j})$

10. A magnetic dipole of dipole moment $\vec{m}$ is placed in a non-uniform field $\vec{B}$. If the position vector of the dipole is $\vec{r}$, the torque acting on the dipole about the origin is: **[GATE 2011]**

(a) $\vec{r}\times(\vec{m}\times\vec{B})$ (b) $\vec{r}\times\vec{\nabla}(\vec{m}.\vec{B})$ (c) $\vec{m}\times\vec{B}$ (d) $\vec{m}\times\vec{B}+\vec{r}\times\vec{\nabla}(\vec{m}.\vec{B})$

11. At a surface current, which one of the magnetostatic boundary condition is NOT CORRECT? **[GATE 2013]**

(a) Normal component of the magnetic field is continuous.
(b) Normal component of the magnetic vector potential is continuous.
(c) Tangential component of the magnetic vector potential is continuous.
(d) Tangential component of the magnetic vector potential is not continuous.

12. A dipole of magnetic moment $\vec{m}$ is placed in an inhomogeneous magnetic field $\vec{B}$. The force experienced by the dipole is :

(a) $\vec{F} = \vec{m}\times(\vec{\nabla}\times\vec{B})$ (b) $\vec{F} = (\vec{m}.\vec{\nabla})\vec{B}$ (c) $\vec{F} = (\vec{\nabla}.\vec{m})\vec{B}$ (d) $\vec{F} = \vec{\nabla}\times(\vec{m}\times\vec{B})$

13. The relation between $\vec{H}.\vec{B}$ and $\vec{M}$ representing the magnetic intensity, magnetic field and magnetic dipole moment vectors, respectively, is

(a) $\vec{H} = -(\mu_0\vec{M}+\vec{B})$ (b) $\vec{H} = \mu_0\vec{M}-\vec{B}$ (c) $\vec{H} = \vec{B}/\mu_0 - \vec{M}$ (d) $\vec{H} = \vec{B}+\mu_0\vec{M}$

14. According to Kirchoff's laws for the circuits, the sum of the currents at any junction is equal to zero. Which of the following equations for the current density $\vec{j}$ describes this situation?

(a) $\vec{\nabla}\times\vec{j} = 0$ (b) $\vec{\nabla}.\vec{j} = 0$ (c) $\nabla^2\vec{j} = 0$ (d) $\partial\vec{j}/\partial t = 0$

15. The magnetic induction $\vec{B}$ and the field $\vec{H}$ inside a bar magnet are

(a) parallel to the bar, and opposite to each other with $\vec{B}$ directed from south to north pole
(b) parallel to each other along the bar, but their magnitude differ by a factor of permeability
(c) parallel to the bar, and opposite to each other with $\vec{B}$ directed from north to south pole
(d) parallel to each other along the bar with equal magnitude

16. In a conducting medium, the magnetic field is given by $H = y^2 z\hat{i} + 2(x+1)yz\hat{j} + (x+1)yz^2\hat{k}$ A/m. The current enclosed by the square loop $y = 1, 0 \le x \le 1, 0 \le z \le 1$ is

(a) $\frac{2}{3}A$ (b) $\frac{4}{3}A$ (c) $\frac{11}{6}A$ (d) $\frac{5}{2}A$

17. Given a uniform magnetic field $\boldsymbol{B} = B_0\hat{k}$ (where B_0 is a constant), a possible choice for the magnetic vector potential $\boldsymbol{A}$ is **[NET Dec. 2015]**

(a) $B_0 y\hat{i}$ (b) $-B_0 y\hat{i}$ (c) $B_0(x\hat{j} + y\hat{i})$ (d) $B_0(x\hat{i} - y\hat{j})$

18. A vector field is given by $\vec{A} = y\hat{i} + z\hat{j} + x\hat{k}$. The curl of the vector is:

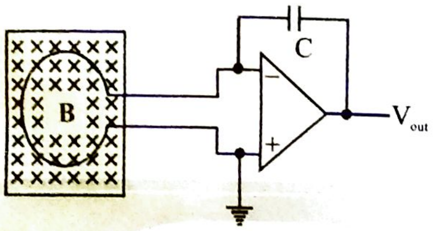
(a) $\hat{i} + \hat{j} - \hat{k}$ (b) $-\hat{i} - \hat{j} - \hat{k}$ (c) $-\hat{i} - \hat{j} + \hat{k}$ (d) $\hat{i} + \hat{j} + \hat{k}$

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-6 : Electromagntic Theory

1. Consider a conducting loop of radius a and total loop resistance R placed in a region with a magnetic field thereby enclosing a flux ϕ_0. The loop is connected to an electronic circuit as shown, the capacitor being initial uncharged. If the loop is pulled out of the region of the magnetic field at a constant speed 'u', the final outpu voltage V_{out} is independent of **[GATE 2010]**



(a) ϕ_0 (b) u (c) R (d) C

2. Which of the following vector fields can represent an electrostatic field?

(a) $\left(2xz - y^2\right)\hat{i} + \left(2xy - z^2\right)\hat{j} + \left(2yz - x^2\right)\hat{k}$

(b) $xy\hat{i} + 2yz\hat{j} + 3xz\hat{k}$ (c) $yz\hat{i} - xz\hat{j} + xy\hat{k}$

(d) $y^2\hat{i} + \left(2xy + z^2\right)\hat{j} + \left(2yz + x^2\right)\hat{k}$ (e) $y^2\hat{i} + \left(2xy + z^2\right)\hat{j} + 2yz\hat{k}$

3. A small magnet is dropped down a long vertical copper tube in a uniform gravitational field. After a long time, the magnet **[JEST 2012]**

(a) Attains a constant velocity (b) moves with a constant acceleration
(c) moves with a constant deceleration (d) executes simple harmonic motion.

4. A thin conducting wire is bent into a circular loop of radius r and placed in a time dependent magnetic field of magnetic induction. **[GATE 2001]**

$$\vec{B}(r) = B_0 e^{-\alpha t}\hat{e}_z, \left(B_0 > 0 \text{ and } \alpha > 0\right),$$

such that, the plane of the loop is perpendicular to $\vec{B}(t)$. Then the induced emf in the loop is :

(a) $\pi r^2 \alpha B_0\, e^{-\alpha t}$ (b) $\pi r^2 B_0\, e^{-\alpha t}$ (c) $-\pi r^2 \alpha B_0\, e^{-\alpha t}$ (d) $-\pi r^2 B_0\, e^{-\alpha t}$

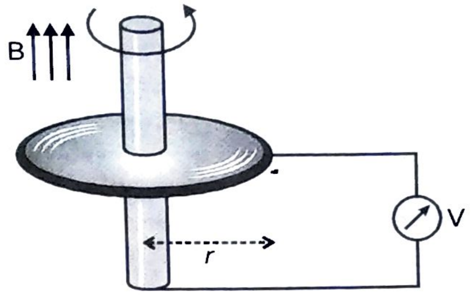
5. Which of the following expressions represents an electric field due to a time varying magnetic field? **[JEST 2015]**

(a) $K(x\hat{x} + y\hat{y} + z\hat{z})$ (b) $K(x\hat{x} + y\hat{y} - z\hat{z})$
(c) $K(x\hat{x} - y\hat{y})$ (d) $K(y\hat{y} - x\hat{y} + 2z\hat{z})$

6. A charged particle is released at time $t = 0$, from the origin in the presence of uniform static electric and magnetic fields given by $\mathbf{E} = E_0\hat{y}$ and $\mathbf{B} = B_0\hat{z}$, respectively. Which of the following statements is true for $t > 0$? **[JEST 2015]**

(a) The particle moves along the x-axis (b) The particle moves in a circular orbit
(c) The particle moves in the (x, y) plane (d) The particle moves in the (y, z) plane

7. A conducting circular disc of radius r and resistivity ρ rotates with an angular velocity ω in a magnetic field B perpendicular to it. A voltmeter is connected as shown in the figure below. **[NET Dec. 2016]**



Assuming its internal resistance to be infinite, the reading on the voltmeter

(a) depends on ω, B, r and ρ

(b) depends on ω, B and r, but not on ρ

(c) is zero because the flux through the loop is not changing

(d) is zero because a current flows in the direction of B

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-7 : Electromagntic Theory

1. In a certain region R, Maxwell's equations for the electric and magnetic fields are given by

$$\nabla.\vec{E}=0,\ \nabla.\vec{B}=0,\ \nabla\times\vec{E}=-\frac{\partial\vec{B}}{\partial t},\ \nabla\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$$ [NET 2008]

We may conclude that
(a) Both the scalar and the vector potential are necessarily constant in the region R.
(b) The electric field $\vec{E}$ and the magnetic field $\vec{B}$ must necessarily be uniform in R.
(c) There are no sources for electric charges and currents in R.
(d) The electric field $\vec{E}$ is necessarily perpendicular to the magnetic field $\vec{B}$ at every point in R.

2. An electromagnetic wave is propagating in free space in the z-direction. If the electric field is given by $E=\cos(\omega t-kz)i$, where $\omega t=ck$, then the magnetic field is given by : [GATE 2003]

(a) $B=(1/c)\cos(\omega t-kz)j$
(b) $B=(1/c)\sin(\omega t-kz)j$
(c) $B=(1/c)\cos(\omega t-kz)i$
(d) $B=(1/c)\cos(\omega t-kz)ji$

Common Data for Q.3 and Q.4

Let $\tilde{E}=\hat{x}E_0\exp\left[i\tilde{k}\cdot\vec{r}-\omega t\right]$, where $\vec{k}=\hat{z}(k\cos\phi+ik\sin\phi)$, $k=1\vec{k}$ and $\hat{x}$, $\hat{y}$ and $\hat{z}$ are cartesian unit vectors, represent an electric field of a plane electro magnetic wave of frequency ω.

3. Which one of the following statements is TRUE? [GATE 2004]
(a) The magnitude of the electric field is attenuated as the wave propagates
(b) The energy of the e.m. wave flows along the x-direction
(c) The magnitude of the electric field of the wave is a constant
(d) The speed of the wave is the same as c (speed of light in free space)

4. The magnetic field $\tilde{B}$ of the wave is : [GATE 2004]

(a) $\hat{y}\frac{k}{\omega}E_0\exp(-zk\sin\phi)\exp\left[i(zk\cos\phi-\omega t)\right]$

(b) $\hat{y}\frac{k}{\omega}E_0\exp(-zk\sin\phi)\exp\left[i(zk\cos\phi-\omega t+\phi)\right]$

(c) $\hat{y}\frac{k}{\omega}E_0\exp\left[i(zk\cos\phi-\omega t+\phi)\right]$

(d) $\hat{y}\frac{k}{\omega}E_0\exp(-zk\cos\phi)\exp\left[i(zk\sin\phi-\omega t)\right]$

5. In a non-conducting medium characterized by $\varepsilon = \varepsilon_0$, $\mu = \mu_0$ and conductivity $\sigma = 0$, the electric field $\left(\text{in Vm}^{-1}\right)$ is given by $\vec{E} = 20\sin\left[10^8 t - kz\right]\hat{j}$. The magnetic field, $\vec{H}\left(\text{in A m}^{-1}\right)$, is given by:

(a) $20k\cos\left[10^8 t - kz\right]\hat{i}$

(b) $\dfrac{20k}{10^8\mu_0}\sin\left[10^8 t - kz\right]\hat{j}$ **[GATE 2009]**

(c) $-\dfrac{20k}{10^8\mu_0}\sin\left[10^8 t - kz\right]\hat{i}$

(d) $-20k\cos\left[10^8 t - kz\right]\hat{j}$

6. Which one of the following sets of Maxwell's equations for time - independent charge density ρ and current density $\hat{J}$ is correct? **[GATE 2006]**

(a) $\vec{\nabla}.\vec{E} = \rho/\varepsilon_0$, $\vec{\nabla}.\vec{B} = 0$, $\vec{\nabla}\times\vec{E} = -\dfrac{\partial\vec{B}}{\partial t}$, $\vec{\nabla}\times\vec{B} = \mu_0\varepsilon_0\dfrac{\partial\vec{E}}{\partial t}$

(b) $\vec{\nabla}.\vec{E} = \rho/\varepsilon_0$, $\vec{\nabla}.\vec{B} = 0$, $\vec{\nabla}\times\vec{E} = 0$, $\vec{\nabla}\times\vec{B} = \mu_0\hat{J}$

(c) $\vec{\nabla}.\vec{E} = 0$, $\vec{\nabla}.\vec{B} = 0$, $\vec{\nabla}\times\vec{E} = 0$, $\vec{\nabla}\times\vec{B} = \mu_0\hat{J}$

(d) $\vec{\nabla}.\vec{E} = \rho/\varepsilon_0$, $\vec{\nabla}.\vec{B} = \mu_0\hat{J}$, $\vec{\nabla}\times\vec{E} = 0$, $\vec{\nabla}\times\vec{B} = \mu_0\varepsilon_0\dfrac{\partial\vec{E}}{\partial t}$

Statement for Linked Answer Q. 7 and Q. 8:

A plane electromagnetic wave has the magnetic field given by $\vec{B}(x,y,z,t) = B_0\sin\left[(x+y)\dfrac{k}{\sqrt{2}} + \omega t\right]\hat{k}$

Where k is the wave number and $\hat{i}$, $\hat{j}$ and $\hat{k}$ are the Cartesian unit vectors is x, y and z directions, respectively.

7. The electric field $\vec{E}(x,y,z,t)$ corresponding to the above wave is given by **[GATE 2011]**

(a) $cB_0\sin\left[(x+y)\dfrac{k}{\sqrt{2}} + \omega t\right]\dfrac{(\hat{i}-\hat{j})}{\sqrt{2}}$

(b) $cB_0\sin\left[(x+y)\dfrac{k}{\sqrt{2}} + \omega t\right]\dfrac{(\hat{i}+\hat{j})}{\sqrt{2}}$

(c) $cB_0\sin\left[(x+y)\dfrac{k}{\sqrt{2}} + \omega t\right]\hat{i}$

(d) $cB_0\sin\left[(x+y)\dfrac{k}{\sqrt{2}} + \omega t\right]\hat{j}$

8. The average Poynting vector is given by **[GATE 2011]**

(a) $\dfrac{cB_0^2}{2\mu_0}\dfrac{(\hat{i}-\hat{j})}{\sqrt{2}}$

(b) $-\dfrac{cB_0^2}{2\mu_0}\dfrac{(\hat{i}-\hat{j})}{\sqrt{2}}$

(c) $\dfrac{cB_0^2}{2\mu_0}\dfrac{(\hat{i}+\hat{j})}{\sqrt{2}}$

(d) $-\dfrac{cB_0^2}{2\mu_0}\dfrac{(\hat{i}+\hat{j})}{\sqrt{2}}$

9. The space-time dependence of the electric field of a linearly polarized light in free space is given by $\hat{x}E_0\cos(\omega t - kz)$ where E_0, ω and k are the amplitude, the angular frequency and the wavevector, respectively. The time averaged energy density associated with the electric field is **[GATE 2012]**

(a) $\dfrac{1}{4}\varepsilon_0 E_0^2$

(b) $\dfrac{1}{2}\varepsilon_0 E_0^2$

(c) $\varepsilon_0 E_0^2$

(d) $2\varepsilon_0 E_0^2$

10. The intensity of a laser in free space is $150\ mW/m^2$. The corresponding amplitude of the electric field of the laser is ______ V/m. $\left(\varepsilon_0 = 8.854\times10^{-12}\ C^2/N.m^2\right)$ **[GATE 2014]**

11. A plane electromagnetic wave travelling in a vacuum is characterised by the electric and magnetic fields

$$\vec{E}=\hat{i}\left(30\pi\ \mathrm{Vm^{-1}}\right)\exp i\left(\omega t+kz\right);\quad \vec{H}=\hat{j}\left(H_0\ \mathrm{Am^{-1}}\right)\exp i\left(\omega t+kz\right)$$

If $\omega, k>0$, the value of H_0 must be **[TIFR 2013]**

(a) 2π (b) 0.67 (c) 0.25 (d) 0.94

12. An electromagnetic wave of frequency ω travels in the x-direction through vacuum. It is polarized in the y-direction and the amplitude of the electric field is E_0. With $k=\omega/c$ where c is the speed of light in vacuum, the electric and the magnetic fields are then conventionally given by **[JEST 2013]**

(a) $\vec{E}=E_0\cos(ky-\omega t)\hat{x}$ and $\vec{B}=\frac{E_0}{c}\cos(ky-\omega t)\hat{z}$

(b) $\vec{E}=E_0\cos(kx-\omega t)\hat{y}$ and $\vec{B}=\frac{E_0}{c}\cos(kx-\omega t)\hat{z}$

(c) $\vec{E}=E_0\cos(kx-\omega t)\hat{z}$ and $\vec{B}=\frac{E_0}{c}\cos(kx-\omega t)\hat{y}$

(d) $\vec{E}=E_0\cos(kx-\omega t)\hat{x}$ and $\vec{B}=\frac{E_0}{c}\cos(ky-\omega t)\hat{y}$

13. A propagating electromagnetic wave is given by $\vec{E}=E_0\left(j+i\hat{k}\right)e^{i(kx-\omega t)}$. The wave is

(a) left circularly polarized (b) right circularly polarized

(c) linearly polarized (d) elliptically polarized

14. The electric field of an electromagnetic wave is given by $\vec{E}=E_0\left(3\hat{i}+4\hat{j}\right)\cos k\left(4x-3y-ct\right)$. The directions of the magnetic field $\vec{B}$ and the poynting vector $\vec{p}$ are

(a) $-\hat{k}, \frac{4\hat{i}+3\hat{j}}{5}$ (b) $\hat{k}, \frac{4\hat{i}-3\hat{j}}{5}$ (c) $\frac{4\hat{i}-3\hat{j}}{5}, \hat{k}$ (d) $\frac{4\hat{i}-3\hat{j}}{5}, \frac{4\hat{i}+3\hat{j}}{5}$

15. The electric and magnetic fields of an electromagnetic wave in vacuum are given by $\mathbf{E}=\hat{i}E_0\sin(kz-\omega t)$ and $\mathbf{B}=\hat{j}B_0\sin(kz-\omega t)$ respectively. Which of the following relatins is correct ?

(a) $k^2E_0=\omega^2B_0$ (b) $\omega E_0=kB_0$ (c) $kE_0=\omega B_0$ (d) $E_0B_0=\omega k$

16. A plane polarized electromagnetic wave in free space at time $t=0$ is given by $\vec{E}(x,z)=10\hat{j}\exp\left[i(6x+8z)\right]$. The magnetic field $\vec{B}(x,z,t)$ is given by **[GATE 2012]**

(a) $\vec{B}(x,z,t)=\frac{1}{c}\left(6\hat{k}-8\hat{i}\right)\exp\left[i(6x+8z-10ct)\right]$. (b) $\vec{B}(x,z,t)=\frac{1}{c}\left(6\hat{k}+8\hat{i}\right)\exp\left[i(6x+8z-10ct)\right]$.

(c) $\vec{B}(x,z,t)=\frac{1}{c}\left(6\hat{k}-8\hat{i}\right)\exp\left[i(6x+8z-ct)\right]$. (d) $\vec{B}(x,z,t)=\frac{1}{c}\left(6\hat{k}+8\hat{i}\right)\exp\left[i(6x+8z+ct)\right]$.

17. The electric and magnetic fields in the charge free region $z>0$ are given by **[NET June 2015]**

$$\vec{E}(\vec{r},t)=E_0e^{-k_1z}\cos(k_2x-\omega t)\hat{j}$$

$$\vec{B}(\vec{r},t)=\frac{E_0}{\omega}e^{-k_1z}\left[k_1\sin(k_2x-\omega t)\hat{i}+k_2\cos(k_2x-\omega t)\hat{k}\right]$$

where ω, k_1 & k_2 are positive constants. The average energy flow in the x-direction is

(a) $\frac{E_0^2k_2}{2\mu_0\omega}e^{-2k_1z}$ (b) $\frac{E_0^2k_2}{\mu_0\omega}e^{-2k_1z}$ (c) $\frac{E_0^2k_1}{2\mu_0\omega}e^{-2k_1z}$ (d) $\frac{1}{2}c\varepsilon_0E_0^2e^{-2k_1z}$

18. The electric field of an electromagnetic wave is given by $\vec{E} = \hat{i}E_0 \sin(ky - \omega t)$, where '$k$' and ω respectively denote the wave vector and angular frequency of the wave. $\hat{i}$, $\hat{j}$ and $\hat{k}$ respectively denote the unit vectors in the x, y and z directions. The magnetic field $\vec{B}$ of the wave is given by

(a) $\hat{k}E_0 k \sin(ky - \omega t)$ (b) $\hat{j}E_0 \cos(ky - \omega t)$

(c) $-\hat{k}\dfrac{E_0\omega}{k}\cos(ky - \omega t)$ (d) $-\hat{k}\dfrac{E_0\omega}{k}\sin(ky - \omega t)$

19. The electric field of a travelling wave is given by $100\cos(10^{9}t - 4x)$, where t is in seconds and x in metres. The speed of the wave is:

(a) 3.0×10^8 m/s (b) 2.5×10^8 m/s (c) 3.0×10^7 m/s (d) 5.0×10^7 m/s

20. The Poynting vector has the dimension of:

(a) Energy / Area (b) Power / Area

(c) Energy / (Charge × Volume) (d) Power / (Charge × Volume)

21. A current I flows in a cylindrical wire of length L and radius a, placed in a uniform electric field, $E = V/L$, parallel to the wire (V is the potential difference between the two ends of the wire). Which of the following statements is correct?

(a) The Poynting vector is zero for this system

(b) The magnitude of Poynting vector is $\dfrac{VI}{2\pi aL}$ and it is directed parallel to the wire

(c) The magnitude of Poynting vector is $\dfrac{VI}{2\pi aL}$ and it points radially inward

(d) The magnitude of Poynting vector is $\dfrac{VI}{2\pi aL}$ and it points radially outward

22. A uniform volume charge density is placed inside a conductor (with resistivity $10^{-2}\ \Omega\text{m}$). The charge density becomes 1/(2.718) of its original value after time ______ femto seconds. (up to two decimal places)

$(\varepsilon_0 = 8.854 \times 10^{-12}$ F/m) **[GATE 2017]**

23. The electric field of an electromagnetic wave is given by $\vec{E} = (2\hat{k} - 3\hat{j}) \times 10^{-3}\sin[10^{7}(x + 2y + 3z - \beta t)]$. The value of β is ($c$ is the speed of light)

(a) $\sqrt{14}c$ (b) $\sqrt{12}c$ (c) $\sqrt{10}c$ (d) $\sqrt{7}c$

24. The charge distribution inside a material of conductivity σ and permittivity ε at initial time $t = 0$ is $\rho(r, 0) = \rho_0$, constant. At subsequent times $\rho(r, t)$ is given by **[NET June 2017]**

(a) ✓ $\rho_0 \exp\left(-\dfrac{\sigma t}{\varepsilon}\right)$ (b) $\dfrac{1}{2}\rho_0\left[1 + \exp\left(\dfrac{\sigma t}{\varepsilon}\right)\right]$

(c) $\dfrac{\rho_0}{\left[1 - \exp\left(\dfrac{\sigma t}{\varepsilon}\right)\right]}$ (d) $\rho_0 \cosh\dfrac{\sigma t}{\varepsilon}$

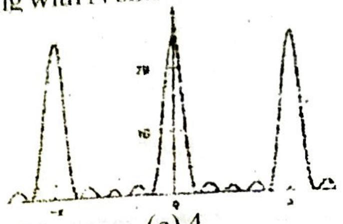
CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-8 : Electromagntic Theory

1. A right circularly polarized beam is incident on a calcite half wave plate. The emergent wave will be
(a) linearly polarized
(b) left circularly polarized
(c) elliptically polarized
(d) unpolarized

2. The diffraction pattern from a grating with N slits is shown in the figure. The value of N is

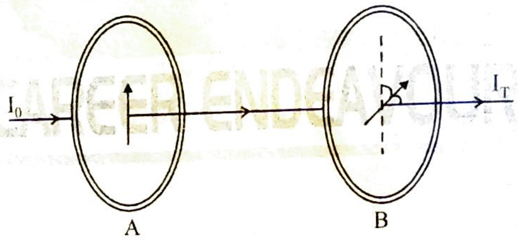


(a) 3
(b) 5
(c) 4
(d) 2

3. In charge free and current free space, the following is true:
(a) $\vec{\nabla}\times\vec{H}=\frac{\partial\vec{B}}{\partial t}$
(b) $\vec{\nabla}\times\vec{H}=0$
(c) $\vec{\nabla}\times\vec{H}=\frac{\partial\vec{D}}{\partial t}$
(d) $\vec{\nabla}\times\vec{H}=-\frac{\partial\vec{D}}{\partial t}$

4. The neutral pion π^0 at rest decays into two photons. One of the photons is right circularly polarized. The other photon is:
(a) Also right circularly polarized.
(b) Left circularly polarized.
(c) Unpolarized.
(d) Plane polarized.

5. Unpolarised light of intensity I_0 Passes successively through two identical linear polarisers A and B, placed such that their polarisation axes are at an angle of 45° (see figure) with respect to one another. **[TIFR 2012]**



Assuming A and B to be perfect polarisers (i.e. no absorption losses), the intensity of the transmitted light will be I_T =
(a) $I_0/4$
(b) $I_0/2\sqrt{2}$
(c) $I_0/2$
(d) $I_0/\sqrt{2}$

6. Can the following scalar and vector potentials describe an electromagnetic field? **[GATE 2007]**

$$\phi(\vec{x},t)=3xyz-4t$$
$$\vec{A}=(\vec{x},t)=(2x-\omega t)\hat{i}+(y-2z)\hat{j}+\left(z-2e^{i\omega t}\right)\hat{k}$$

where, ω is a constant.
(a) Yes, in the Coulomb gauge
(b) Yes, in the Lorentz gauge
(c) Yes, provided $\omega=0$
(d) No.

7. A plane electromagnetic wave traveling in free space is incident normally on a glass plate of refractive index 3/2. If there is no absorption by the glass, Its reflectivity is **[GATE 2012]**

(a) 4% (b) 16 % (c) 20% (d) 50%

8. Unpolarized light falls from air to a planar air-glass interface (refractive index of glass is 1.5) and the reflected light is observed to be plane polarized. The polarization vector and the angle of incidence q_i are : **[GATE 2008]**

(a) Perpendicular to the plane of incidence and $\theta_i = 42^\circ$

(b) Parallel to the plane of incidence and $\theta_i = 56^\circ$

(c) Perpendicular to the plane of incidence and $\theta_i = 56^\circ$

(d) Parallel to the plane of incidence and $\theta_i = 42^\circ$

9. A Plane electromagnetic wave of frequency w is incident normally on an air-dielectric interface. He dielectric is linear, isotropic, non-magnetic and its refractive index is n. The reflectance (R) and transmittance (T) from the interface are : **[GATE 2004]**

(a) $R = \left(\frac{n-1}{n+1}\right)^2, T = \frac{4n}{(n+1)^2}$ (b) $R = -\left(\frac{n-1}{n+1}\right), T = \frac{2}{(n+1)^2}$

(c) $R = \left(\frac{n-1}{n+1}\right)^3, T = \frac{4n^3}{(n+1)^3}$ (d) $R = \left(\frac{(n-1)^2}{n+1}\right), T = \frac{4n^2}{(n+1)^2}$

10. In a two beam interference pattern, the maximum and minimum intensity values are found to be 25 I_0 and 9 I_0 respectively, where I_0 is a constant. The intensities of the two interfereing beams are : **[GATE 2002]**

(a) 16 I_0 and I_0 (b) 5 I_0 and 3 I_0 (c) 17 I_0 and 8 I_0 (d) 8 I_0 and 2 I_0

11. A plane electromagnetic wave incident normally on the surface of a material is partially reflected. Measurements on the standing wave in the region in front of the interface show that the ratio of the electric field amplitude at the maxima and the minima is 5. The ratio of the reflected intensity to the incident intensity is

(a) 4/9 (b) 2/3 (c) 2/5 (d) 1/5 **[NET Dec. 2014]**

12. Given any arbitrary electric and magnetic field $\vec{E}(\vec{r},t)$ and $\vec{E}(\vec{r},t)$, it is always possible to choose the scalar potential $\phi(\vec{r},t)$ and vector potential $\vec{A}(\vec{r},t)$ such that **[NET 2008]**

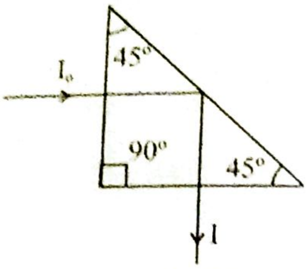
(a) $\vec{A}(\vec{r},t)$ is identically zero.

(b) $\phi(\vec{r},t)$ is identically zero.

(c) $|\vec{A}(\vec{r},t)|$ is any given non-zero constant.

(d) The conditions $\nabla.\vec{A} = 0$ and $\frac{1}{c}\frac{\partial\phi}{\partial t} + \nabla.\vec{A} = 0$ are simultaneously satisfied.

13. Circularly polarized light with intensity I_0 is incident normally on a glass prism as shown in the figure. The index of refraction of glass is 1.5. The intensity I of light emerging from the prism is: **[NET June 2011]**



(a) I_0 (b) $0.96\ I_0$ (c) $0.92\ I_0$ (d) $0.88\ I_0$.

14. In an interference pattern formed by two coherent sources, the maximum and the minimum of the intensities are $9I_0$ and I_0, respectively. The intensities of the individual waves are **[GATE 2014]**

(a) $3I_0$ and I_0 (b) $4I_0$ and I_0 (c) $5I_0$ and $4I_0$ (d) $9I_0$ and I_0

15. Which of the following is Lorentz Invarient **[NET June 2009]**

(a) $E^2 - B^2C^2$ (b) $\vec{E} \times \vec{B}$ (c) $E^2 - BC^2$ (d) $\vec{E} \times \vec{C}$

16. An electron is moving with an acceleration 10 m/s² whereas a positron is moving with an acceleration 20 m/s². The ratio of the power radiated by the positron to that of electron is:

(a) 2 (b) 1/2 (c) 1/4 (d) 4

17. When a plane electromagnetic wave is incident angle i= 60°, the reflected light is completely polarized. The dielectric constant is

(a) 4/3 (b) $\sqrt{3}$ (c) 2 (d) 3

18. A dipole is formed by charges q and –q. The energy radiated by the dipole is maximum.

(a) Along the line joining the charges
(b) Along the line perpendicular to the dipole and passing midway between the dipole.
(c) Along the line inclined to the dipole axis at + 45°.
(d) At the centre of the dipole.

19. The ratio of cyclotron frequencies of an α-particle and a proton moving in the same magnetic field $\vec{B}$ is:

(a) 1/2 (b) 2 (c) 4 (d) 1/4

20. In an electromagnetic field, which one of the following remains invariant under Lorentz transformation? **[GATE 2006]**

(a) $\vec{E} \times \vec{B}$ (b) $E^2 - c^2B^2$ (c) B^2 (d) E^2

21. The electric (E) and magnetic (B) field amplitudes associated with an electromagnetic radiation from a point source behave at a distance r from the source as : **[GATE 2005]**

(a) E = constant, B = constant (b) $E \propto \frac{1}{r}, B \propto \frac{1}{r}$

(c) $E \propto \frac{1}{r^2}, B \propto \frac{1}{r^2}$ (d) $E \propto \frac{1}{r^3}, B \propto \frac{1}{r^3}$

Electromagnetic waves are propagating along a hollow, metallic waveguide whose cross-section is a square of side W. The minimum frequency of the electromagnetic waves is :

(a) c/W (b) 2c/W (c) $\pi c / W$ (d) $\sqrt{2}\,\pi c / W$ **[GATE 2003]**

23. Consider a rectangular wave guide with transverse dimensions 2 m × 1 m driven with an angular frequency $\omega = 10^9$ rad/s. Which transverse electric (TE) modes will propagate in this wave guide? **[NET June 2015]**

(a) TE_{10}, TE_{01} and TE_{20}
(b) TE_{10}, TE_{11} and TE_{20}
(c) TE_{01}, TE_{10} and TE_{11}
(d) TE_{01}, TE_{10} and TE_{22}

24. Sunlight is incident on the surface of the sea at an angle θ. A sailor viewing through a rotating polaroid can almost block the reflected light by adjusting the angle of the polaroid. The value of θ is about (Refractive index of water is 1.33):

(a) 57°
(b) 53°
(c) 49°
(d) 41°

25. Two coherent monochromatic light beams of intensities I and 4I are superimposed. The maximum and minimum possible internsities in the resulting beam are

(a) 3I and I
(b) 5I and 3I
(c) 7I and 5I
(d) 9I and I

26. The conductors in a 0.75 km long two-wire transmission line are separated by a centre-to-centre distance of 0.2m. If each conductor has a diameter of 4cm, then the capacitance of the line is **[JEST 2013]**

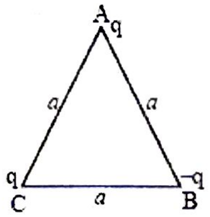
(a) 8.85 μF
(b) 88.5 nF
(c) 8.85 pF
(d) 8.85 nF

CSIR-UGC-NET/JRF|GATE-PHYSICS

ELECTROMAGNETIC THEORY

Assignment-9 : Electromagntic Theory

1. Three point charges are placed at the corners of an equilateral triangle of side 'a' as shown in the figure. Magnitude of force on charge at A is:



2. Calculate total charge in the following cases.

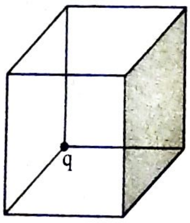
(i) A infinitely long line charge lying along z axis has linear charge density $\lambda(z)=\dfrac{\lambda_o}{1+z^2}$

(ii) A circular disc of radius R has surface charge density $\sigma(r,\phi)=\sigma_o r^2\sin^2\phi$

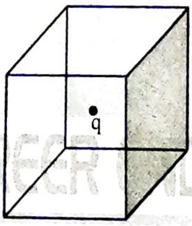
(iii) A spherical shell of radius R has surface charge density $\sigma(\theta)=\sigma_o\cos^2\theta$

3. Calculate the flux of $\vec{E}$ through the shaded side?

(i)

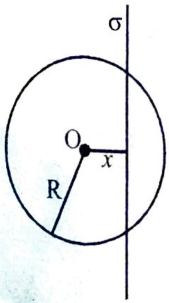


(ii)



4. A cube of side 'a' lies in the first octant with one corner at origin. An electric field $\vec{E}=E_0\left(1-\dfrac{x^2}{a^2}\right)\hat{i}$ exists in space. Total electric flux through the cube is

10. A plane sheet of surface charge density σ is inserted into a sphere of radius R. The perpendicular distance of the plane from the centre is x. Calculate the flux passing through the sphere.



11. Electric field in a region is given to be $\vec{E} = \frac{1}{r}(\alpha\hat{r} + \beta\sin\theta\cos\phi\hat{\phi})$, calculate:

(i) The electric flux passing through a sphere of radius R centered at the origin.

(ii) Charge density ρ corresponding to this electric field.

(iii) Total charge enclosed by the sphere.

12. Determine which of the following are genuine electric fields (Electrostatic fields)

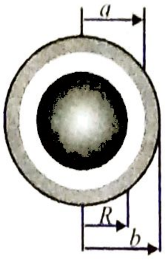
(a) $\vec{E}_1 = 5x^3\,\hat{x} + 15x^2y\,\hat{y}$

(b) $\vec{E}_2 = 2s(z+1)\sin\phi\,\hat{s} + s(z+1)\cos\phi\,\hat{\phi} + s^2\sin\phi\,\hat{z}$

(c) $\vec{E}_3 = \frac{5}{r}\sin\theta\cos\phi\,\hat{r}$

13. The electric potential of some configuration is given by the expression $V(r) = A\frac{e^{-\lambda r}}{r}$, where A and λ are constants. Find the electric field $\vec{E}(r)$, the charge density $\rho(r)$, and the total charge Q.

14. A metal sphere of radius R, carrying charge q, is surrounded by a thick concentric metal shell (inner radius a, outer radius b, as shown in figure). The shell carries no net charge.



(a) Find the surface charge density σ at R, at a, and at b.

(b) Find the potential at the center, using infinity as the reference point.

(c) Now the outer surface is touched to a grounding wire, which lowers its potential to zero (same as at infinity).

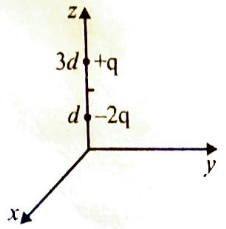
How do your answers to (a) and (b) change?

15. Calculate the workdone in assembling the charge configuration containing three points charges +q, −q and +q at the vertices of an equilateral triangle with side a.

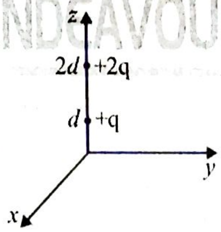
16. A sphere of radius R carries a charge density $\rho(r) = kr$ (where k is a constant). Find the energy of this charge configuration.

17. Find the force on the charge $+q$ in figure. (The xy plane is a grounded conductor).

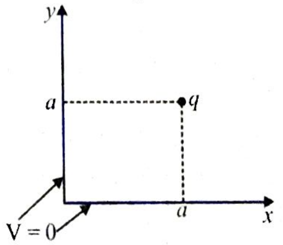
(a)



(b)



18. Two semi-infinite grounded conducting planes meet at right angles. In the region between them, there is a point charge q, situated as shown in figure. Set up the image configuration, and calculate the potential in this region. What is the force on q?



19. Find the electric field at (0, 3, 4)m due to a point charge $q = 1\mu C$ at (1, 1, 1).

20. Find the electric field inside and outside a uniformly charged solid sphere of radius R and total charge q.

21. Determine the electric field due to the following potentials:
(a) $V = x^2 + 2y^2 + 4z^2$ (b) $V = \sin(x^2 + y^2 + z^2)^{1/2}$
(c) $V = r^2(z + 1)\sin\phi$ (d) $V = e^{-r}\sin\theta\cos 2\phi$

22. Two dipoles with dipole moments $-5\hat{z}$ nCm and $9\hat{z}$ nCm are located at points (0, 0, −2) and (0, 0, 3), respectively. Find the potential at the origin.

23. A static charge distribution has the form

$$\rho = \rho_0\left(\frac{r_0}{r}\right)^2 e^{-r/r_0}\cos^2\phi$$

Calculate radial component of the dipole moment of the charge distribution.

24. A spherical shell of radius R carries a surface charge density $\sigma = K\cos\theta$ where K is some constant. Calculate dipole moment of the spherical shell.

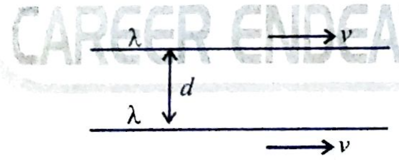
25. A thin insulating rod, running from $z = -a$ to $z = +a$, carries the indicated line charges. In each case, find the dipole moment and leading term in the multipole expansion of the potential:
(a) $\lambda = k\sin(\pi z/a)$, (b) $\lambda = k\cos(\pi z/a)$, where k is a constant.

26. A dielectric cube of side a, centered at the origin, carries a "frozen-in" polarization $\vec{P} = kr$, where k is a constant. Find all the bound charges, and check that they add up to zero.

27. A spherical conductor of radius a carries a charge Q. It is surrounded by a linear dielectric material of susceptibility (χ_e) upto radius b. Find the energy of this configuration.

28. Two extensive homogeneous isotropic dielectric meet on plane $z = 0$, for $z > 0$, $\varepsilon_{r1} = 4$ and for $z < 0$, $\varepsilon_{r2} = 3$. A uniform electric field $\vec{E}_1 = 5\hat{i} - 2\hat{j} + 3\hat{k}$ KV/m exists for $z \geq 0$ find.
(a) E_2 for $z \leq 0$ (b) $\vec{D}_1$ and $\vec{D}_2$ (c) the angles E_1 and E_2 makes with the interface (d) the energy densities (in J/m³) in both dielectrics.

29. Suppose you have two infinite straightline changes λ, a distance d apart, moving along at a constant speed v. How great would v have to be in order for the magnetic attraction to balance the electrical repulsion?



30. In the region $0 < r < 0.5\,m$, in cylindrical coordinates, the current density is $\vec{J} = 4.5e^{-2r}\hat{z}\left(A/m^2\right)$

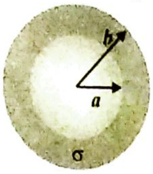
and $\vec{J} = 0$ elsewhere. Use Ampere's law to find $\vec{B}$.

31. Given the general vector field $\vec{A} = 5r\sin\phi\hat{z}$ in cylindrical coordinates, find $\vec{B}$ at $(2, \pi, 0)$.

32. Given the general vector field $\vec{A} = 10\sin\theta\hat{\theta}$ in spherical coordinates, find $\vec{B}$ at $(2, \pi/2, 0)$.

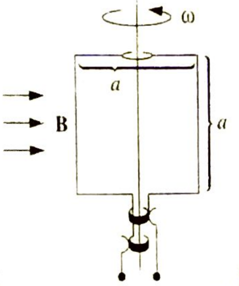
33. An infinitey long circular cylinder carries a uniform magnetization **M** parallel to its axis. Find the magnetic field (due to **M**) inside and outside the cylinder.

34. Two concentric metal spherical shells, of radius a and b, respectively, are separated by weakly conducting material of conductivity σ.



(a) If they are maintained at a potential difference V, what current flows from one to the other?
(b) What is the resistance between the shells?

35. A square loop (side a) is mounted on a vertical shaft and rotated at angular velocity ω. A uniform magnetic field **B** points to the right. Find the $\varepsilon(t)$ for this alternating current generator.



36. A long solenoid, of radius a, is driven by an alternating current, so that the field inside is sinusoidal : $\vec{B}(t) = B_0 \cos(\omega t)\hat{z}$. A circular loop of wire, of radius a/2 and resistance R, is placed inside the solenoid, and coaxial with it. Find the current induced in the loop, as a function of time.

37. Find the self-inductance of a toroidal coil with rectangular cross section (inner radius a, outer radius b, height h), which carries a total of N turns.

38. A circular-section conductor of radius 1.5mm carries a current $i_c = 5.5\sin\left(4\times10^{10}t\right)(\mu A)$. What is the amplitude of the displacement current density, if $\sigma = 35\ MS/m$ and $\in_r = 1$?

39. Suppose the (electrically neutral) yz plane a time-dependent but uniform surface current $K(t)\hat{z}$. Find the electric and magnetic fields at a height x above the plane if a constant current is turned on at $t = 0$

$$K(t) = \begin{cases} 0, & t \le 0 \\ K_0, & t > 0 \end{cases}$$

40. A freely rotating disc is pierced through by an infinite super conducting solenoid containing a magnetic flux ϕ. A charge Q is fixed to the disc at distance R from the centre of the solenoid. If the solenoid is heated and it loses its magnetic field in time T. Calculate net angular momentum acquired by the disc.

41. The electric field of an electromagnetic wave in vacuum is given by

$$\vec{E} = 30\cos\left(2\pi\times10^8 t - \frac{2\pi}{3}x\right)\hat{y}$$

where, $\vec{E}$ is in voltmeter, t is in seconds, x in meter.

Determine,

(a) the frequency f	(b) wave velocity
(c) wavelength λ	(d) direction of propagation
(e) magnetic field with direction	(e) state of polarization.

42. In free space, $\vec{E} = 20\cos(\omega t - 50x)\hat{y}$ v/m. Calculate

(a) $\vec{J}_d$ (b) $\vec{H}$ (c) ω

43. In free space $\vec{E}(z,t) = 50\cos(\omega t - \beta z)\hat{x}(V/m)$. Find the average power crossing a circular area of radius 2.5 m in the plane z = constant.

44. The electric field component of a plane electromagnetic wave are

$$\vec{E}_1 = 2E_0\cos(\omega t - kz + \phi)\hat{i}$$
$$\vec{E}_2 = E_0\sin(\omega t - kz)\hat{j}$$

Draw the diagram showing the SOP for (i) $\phi = 0$, (ii) $\phi = \frac{\pi}{2}$ and (iii) $\phi = \frac{\pi}{4}$

45. A wave is incident at an angle of 30° from air to toflon, $\epsilon_r = 2.1$. Calculate the angle of transmission, and repeat with an interchange of the regions.

46. A charge particle q performing simple harmonic motion with amplitude A and angular frequency ω. Calculate power radiated by the charge particle.

47. A hollow rectangular wave guide has a = 6 cm and b = 4cm. The frequency of the incident signal is 3 Gz. Calculate (i) λ_c, (ii) λ_g,(iii) v_p and (iv) v_g.

ea of

on,

ω.

is